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COST BENEFIT STUDY OF THE ELECTRIFICATION OF THE BC RAIL TACHEEDA TO PRINCE GEORGE LINE

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November, 1985

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17. Abstract

This study examined the capital, operating and maintenance costs associated with extending electrified unit coal train operation on the Tacheeda to Prince George section of BC Rail's mainline. These costs were compared to those of the present diesel-electric powered unit coal train operation to determine the economic benefits that may be realized as a result of the electrification. The electrification of the Prince George-Tacheeda portion of the mainline would require a capital investment of approximately $21.2 million, including the purchase of electric locomotives. It is anticipated that the return on investment to be realized by electrifying would be 6.8% at 8.5 million annual coal tonnage, 15.5% at 13.5 million tons and 20.7% at 17 million tons.

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17. Résumé

Cette étude a examiné les coûts d'investissement, d'opération et d'entretien associés à l'extension de l'électrification de l'opération de trains de charbon bloc sur la ligne principale de BC Rail entre Tacheeda et Prince George. Ces coûts ont été comparés à ceux de la présente opération de trains de charbon bloc tractés par des locomotives diesel-électriques, afin de déterminer les bénéfices financiers qui pourraient être réalisés suite à l'électrification. L'électrification de la ligne principale entre Prince George et Tacheeda demanderait un investissement d'environ $21.2 million, incluant l'achat de locomotives électriques. On s'attend à ce que l'électrification génère un retour sur l'investissement de 6.8% pour un tonnage annuel de 8.5 million de tonnes de charbon, 15.5% pour 13.5 million de tonnes et 20.7% pour 17 million de tonnes.

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COST BENEFIT STUDY OF THE ELECTRIFICATION

OF THE BC RAIL TACHEEDA TO PRINCE GEORGE LINE

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COST BENEFIT STUDY OF THE ELECTRIFICATION OF THE BC RAIL TACHEEDA TO PRINCE GEORGE LINE

1.0 INTRODUCTION

1.1 Background

In December 1983 BC Rail Ltd. initiated 50,000 volt electrified unit train operation on the Tumbler Subdivision (formerly called the Tumbler Ridge Branch Line) to service two coal mines in northeastern British Columbia (see fig. 1). Four 6000 hp electric locomotives (2 units head end, 2 pusher units) are used to transport 8918 metric tonnes of coal on 1.2% compensated grades between the mine sites near Tumbler Ridge, B.C., and BC Rail's mainline at Tacheeda, a distance of 139 km. The pusher units are only required for the loaded coal trains operating on the uphill grades. As a result, the two pusher units are captive between Km 118 and Km 72. At Tacheeda, the electric locomotives are replaced with three 3000 hp diesel electric locomotives for the trip to Prince George (112 km). At Prince George, the unit train is interchanged to Canadian National Railway for the journey to the coal port at Prince Rupert, B.C.

It was recognized that the extension of electrified train operation to include the portion of BC Rail's mainline between Tacheeda and Prince George may provide significant economic benefits. In May, 1985, the Transportation Development Centre of Transport Canada commissioned BC Rail to do a cost-benefit feasibility report to study the economic benefits of electrifying the Tacheeda to Prince George section.

1.2 Purpose

This study examines the capital, operating and maintenance costs associated with extending electrified unit coal train operation on the Tacheeda to Prince George section of BC Rail's mainline. These costs are to be compared to those of the present diesel-electric powered unit coal train operation to determine the economic benefits that may be realized as a result of the electrification.

2.0 STUDY APPROACH & METHODOLOGY

The experience and knowledge gained by BC Rail during the construction, testing, commissioning, maintenance and operation of the Tumbler Ridge electrified line was applied. The following methodology was used:

A. A modified train performance calculator (TPC) was developed to utilize the GF6C electric locomotive tractive effort and efficiency curves derived from the locomotive testing and commissioning programs.

B. The TPC model was run for a single loaded train operating between Quintette Load-out and Tacheeda. The predicted power profile was compared to the actual power profile measured at Tumbler Substation.

C. A set of TPC runs between Quintette Load-out and Prince George were performed based on BC Rail's train schedules. Power profiles were produced for:

i) a single loaded coal train southbound between Quintette Load-out and Prince George

ii) a single empty coal train northbound between Prince George and Quintette Load-out

iii) total power required for the Quintette Load-out to Tacheeda section

iv) total power required for the Tacheeda to Prince George section

v) total power required for the Quintette Load-out to Prince George section

The results of these TPC runs were used to calculate the diesel fuel and electric "fuel" costs associated with electric and diesel-electric train operation.

D. A voltage profile program was developed to combine the results of the TPC with the electric parameters of the catenary system measured during the Tumbler Subdivision System Tests. This program was used to evaluate the various power supply configurations for the Tacheeda to Prince George section.

E. The electrical parameters of the Tumbler Subdivision electrified system measured during the commissioning tests were used in an Electrical Magnetic Transients Program (EMTP) to study the harmonic effects of various power supply, filtering and locomotive configurations.

F. The catenary system was reviewed to identify potential savings that may be realized through design changes.

G. Capital, operating and maintenance cost estimates were developed for an all electric unit coal train operation between Prince George and Tacheeda. A similar estimate was prepared for retaining the existing diesel-electric

operation. These two cost estimates were analyzed to determine the economic benefit of electrifying the Prince George to Tacheeda section of BC Rail's mainline.

H. The economic analysis was performed for various annual tonnages of coal movements:

1) 8.5 million tonnes per year (953 round trips/year).
2) 13.5 million tonnes per year (1514 round trips/year).
3) 17.0 million tonnes per year (1906 round trips/year).

3.0 FIXED PLANT FACILITIES

3.1 Catenary System

The extension of the catenary system from the existing end of Electrified Territory at Tacheeda (Mile 534.5 of the Chetwynd Subdivision) to the Prince George locomotive shop (Mile 461) (see fig. 2) was considered in this study. The electrification of sidings at McIntyre (Mile 525), Odell (Mile 496), and Quaw (Mile 480), is included (see fig. 4). All sidings would be fed via sectionalizing motor operated disconnects remotely operated from the North Vancouver control centre.

3.2 Substation

A 230/50 kV traction substation is proposed to be constructed trackside at Mile 484 with a direct primary tap to B.C. Hydro's 230 kV line 2L97. This location would eliminate the requirement for B.C. Hydro to install a 230 kV feeder position at their substation and would also eliminate the requirement for a woodpole 50 kV feeder line (see Appendix D).

The substation would contain a single 25/33 MVA transformer position with a primary and a standby 50 kV catenary feeder position. One of the existing power transformers at the Tumbler Substation will serve as a spare common to the Mile 484 and Tumbler Substations (see fig. 3).

Due to the low power factor of the GF6C locomotives (see fig. E3, Appendix E) at the operating speed of unit coal trains, a shunt capacitor will be required at the substation to limit reactive demand. The shunt capacitor will be tuned with a series reactor to also provide control of harmonic distortion caused by the GF6C locomotives.

3.3 Filter Station

The EMTP analysis indicates that the proposed electrification extension will require a damping filter in the vicinity of Tacheeda to limit harmonic overvoltages (see Appendix C).

4.0 MOTIVE POWER REQUIREMENTS

An analysis of the train schedules shown in figures A1, A2, A3 (Appendix A) indicates that the addition of four 6000 hp electric locomotives to the present fleet of seven 6000 hp electric locomotives will be required to move annual tonnages up to 17.0 million tonnes for the combined mine sites to Tacheeda and Tacheeda to Prince George operation.

The additional four 6000 hp electric locomotives supplied would replace six 3000 hp diesel-electric locomotives that CN Rail is currently contractually responsible to provide. It is assumed that CN Rail will reimburse BC Rail for the capital cost of diesel-electric locomotives released by electrifying the Prince George to Tacheeda section (see Appendix B) on a one-to-one basis (i.e. although six 3000 hp diesel-electric locomotives would be released, CN Rail would reimburse BC Rail for the equivalent capital cost of four 3000 hp diesel-electric locomotives).

5.0 MAINTENANCE COSTS FOR ELECTRIFIED OPERATION

5.1 Electric Locomotive Maintenance

The anticipated annual maintenance cost per electric locomotive is $88,800 (see Table C1, Appendix C), and is independent of the annual mileage until approximately 240,000 kilometers per year per locomotive is exceeded. The majority of electric locomotive maintenance for annual unit mileages of less than 240,000 kilometers is calendar dictated (i.e. daily, monthly, yearly inspection and maintenance program). The anticipated annual mileage per electric locomotive for the Prince George to Tumbler Ridge section is:

8.5 million tonnes per year	115,000 kilometers per year
13.5 million tonnes per year	165,000 kilometers per year
17.0 million tonnes per year	208,000 kilometers per year

5.2 Catenary, Substation and Filter Station Maintenance

It is expected that a single three-man crew plus one foreman would be required to maintain the substation, harmonic filter station and catenary section from Tacheeda to Prince George. The annual maintenance costs are estimated at $235,000 and are independent of the number of train movements. Increased train movements may limit track access and careful scheduling of maintenance activities will be required.

6.0 ANNUAL OPERATING COSTS - DIESEL-ELECTRIC LOCOMOTIVES, PRINCE GEORGE TO ANZAC

The annual maintenance and fuel costs for operating diesel-electric locomotives on the Prince George to Tacheeda section of line are summarized in Table 1 (see Appendix B for detailed calculations).

The use of mixed diesel-electric and electric locomotives for the journey between Prince George and Tumbler makes it necessary to exchange the electric units for diesel-electric units at Tacheeda when southbound and vice versa when northbound. The additional annual labour cost of this power exchange (swap) is shown in Table 1.

TABLE 1
Annual Diesel-Electric Operating Costs
Prince George to Tacheeda

Million Tonnes Per Year	8.5	13.5	17.0
Locomotive Maintenance	$1,216,000	$1,930,000	$2,430,000
Diesel Fuel	2,079,000	3,304,000	4,159,000
Motive Power Swap	67,000	106,000	133,000
Total	$3,362,000	5,340,000	6,722,000

7.0 ANNUAL ELECTRIC LOCOMOTIVE OPERATING COSTS

The cost of electrified train operation is shown in Table 2. Detailed calculations are included in Appendix C.

TABLE 2
Annual Electric Operating Costs
Prince George to Tacheeda

Million Tonnes Per Year	8.5	13.5	17.0
Demand	$363,000	$363,000	$363,000
Energy	310,000	492,000	619,000
Locomotive Maintenance	355,000	355,000	355,000
Catenary Maintenance	235,000	235,000	235,000
Total	$1,263,000	$1,445,000	$1,572,000

8.0 SUMMARY AND CONCLUSIONS

BC Rail's operating experience with the electrified Tumbler subdivision over the past two years has shown that electrification of heavy haul unit trains operating on steep grades are both feasible and offer considerable savings in operating costs. Technical problems associated primarily with the electric locomotives and with the corrosion of the catenary system in the long tunnels have resulted in the operating savings not being realized during the first year of operation.

Currently the savings projected with electrification of the Tumbler subdivision are being realized.

The electrification of the Prince George-Tacheeda portion of the mainline would require a capital investment of approximately $21.2 million, including the purchase of electric locomotives. It is anticipated that annual operating savings to be realized by electrifying would be:

Annual Coal Tonnage (millions)	8.5	13.5	17.0
Net annual savings	$2,099,000	$3,897,000	$5,152,000
Return on investment	6.8%	15.5%	20.7%

No attempt has been made to predict the long term pricing of diesel fuel due to its volatility. Any differential increase in the price of diesel fuel in relation to electricity would result in a greater rate of return for electrification.

To date, a long term contract with the electric utility has not been finalized. The establishment of a more favourable rate structure, particularly in the demand charges, will increase the attraction of electrification.

At the present annual tonnages and rate structures for diesel fuel and electricity, the electrification of the Prince George to Tacheeda portion is economically feasible only if sufficient grants are available to enable BC Rail to achieve a reasonable rate of return on its investment.

It is expected that the knowledge gained with the completion of the electrification between Prince George and the coal mines will provide the technical and operating experience invaluable for the application of railway electrification on a national basis.

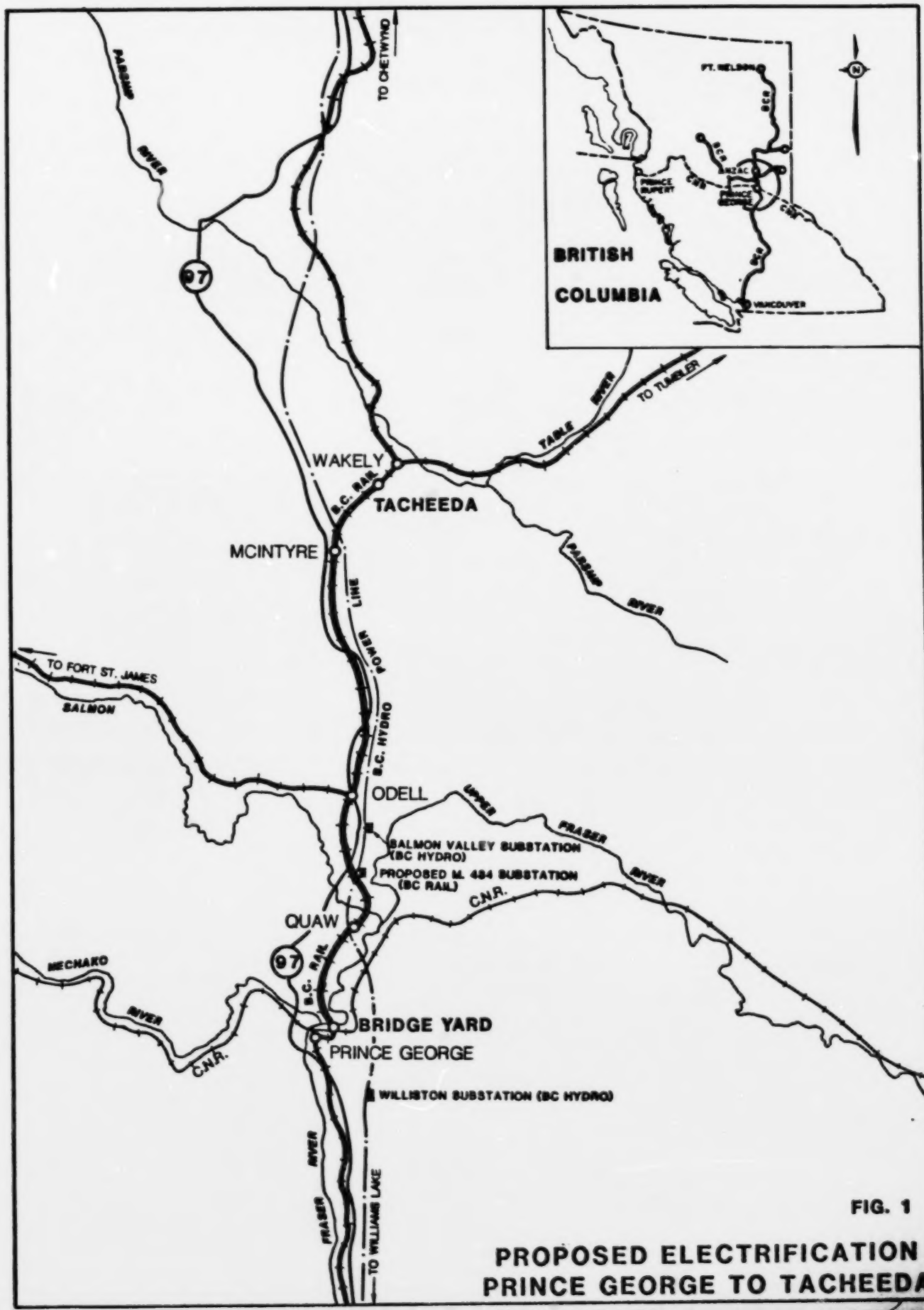


FIG. 1

PROPOSED ELECTRIFICATION PRINCE GEORGE TO TACHEEDA

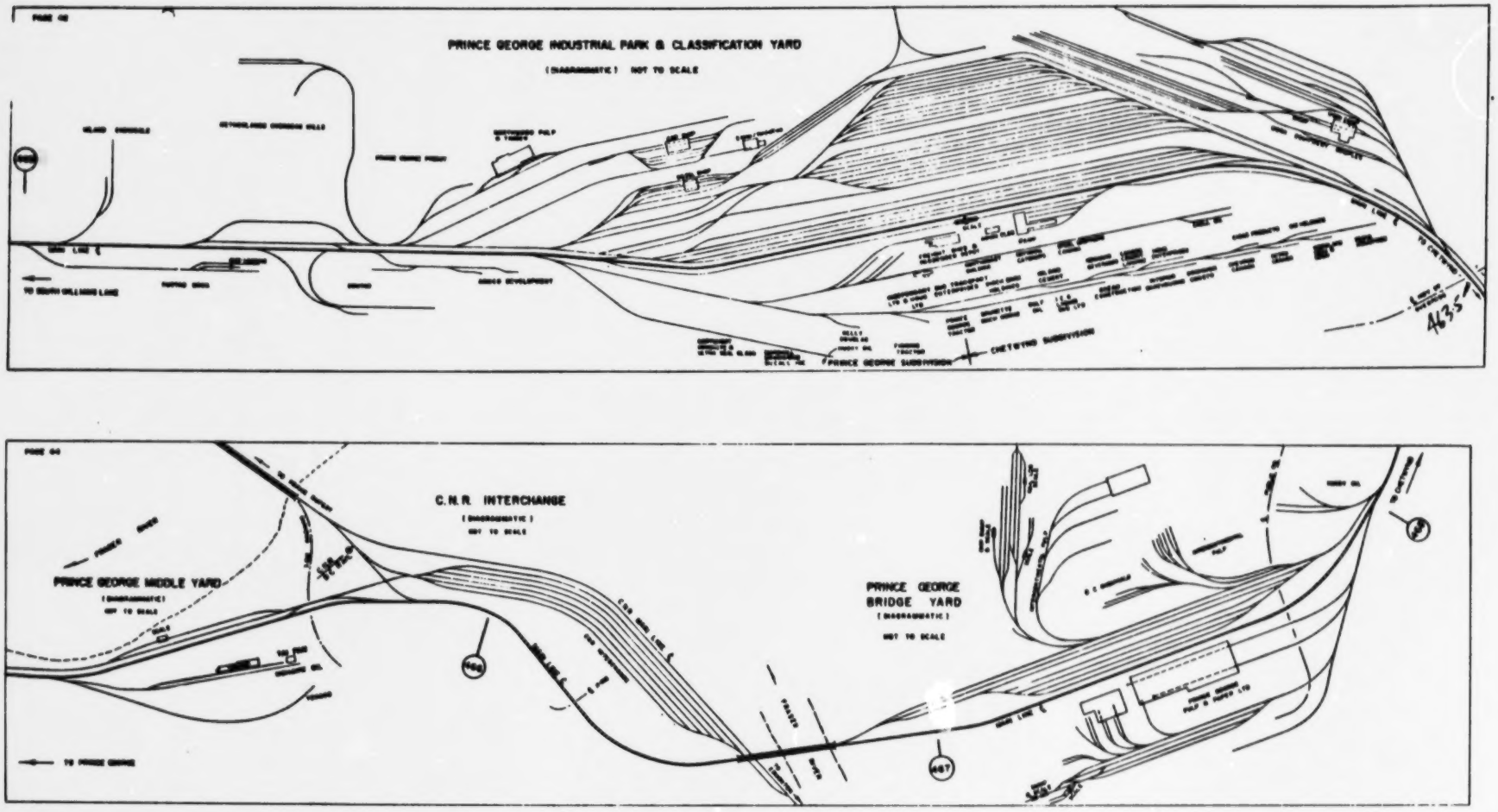
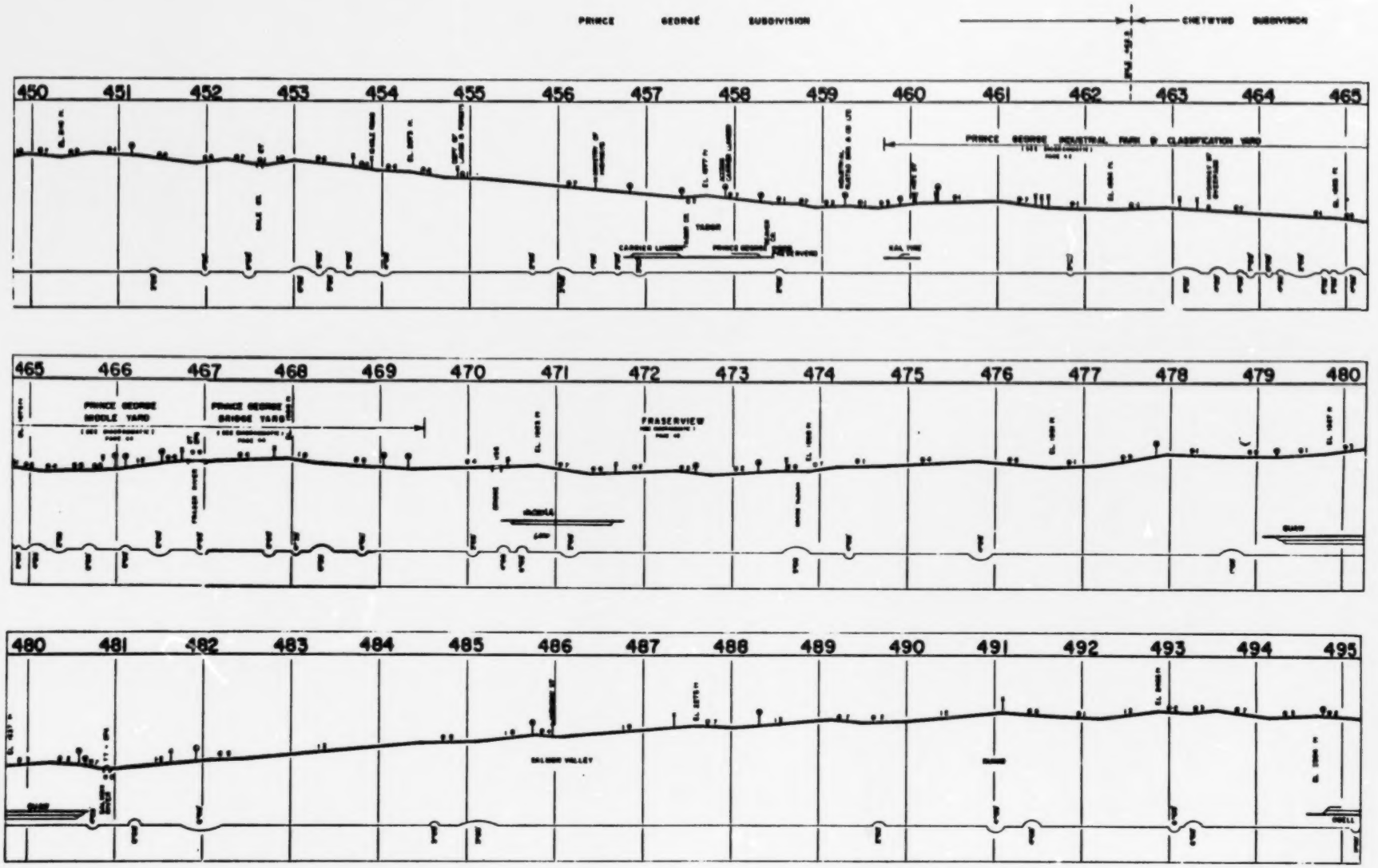


fig 2 EXCERPT FROM
B·C·RAIL CONDENSED PROFILE No 3
PRINCE GEORGE TO TUMBLER RIDGE


PRINCE GEORGE SUBDIVISION
CHETWYND SUBDIVISION
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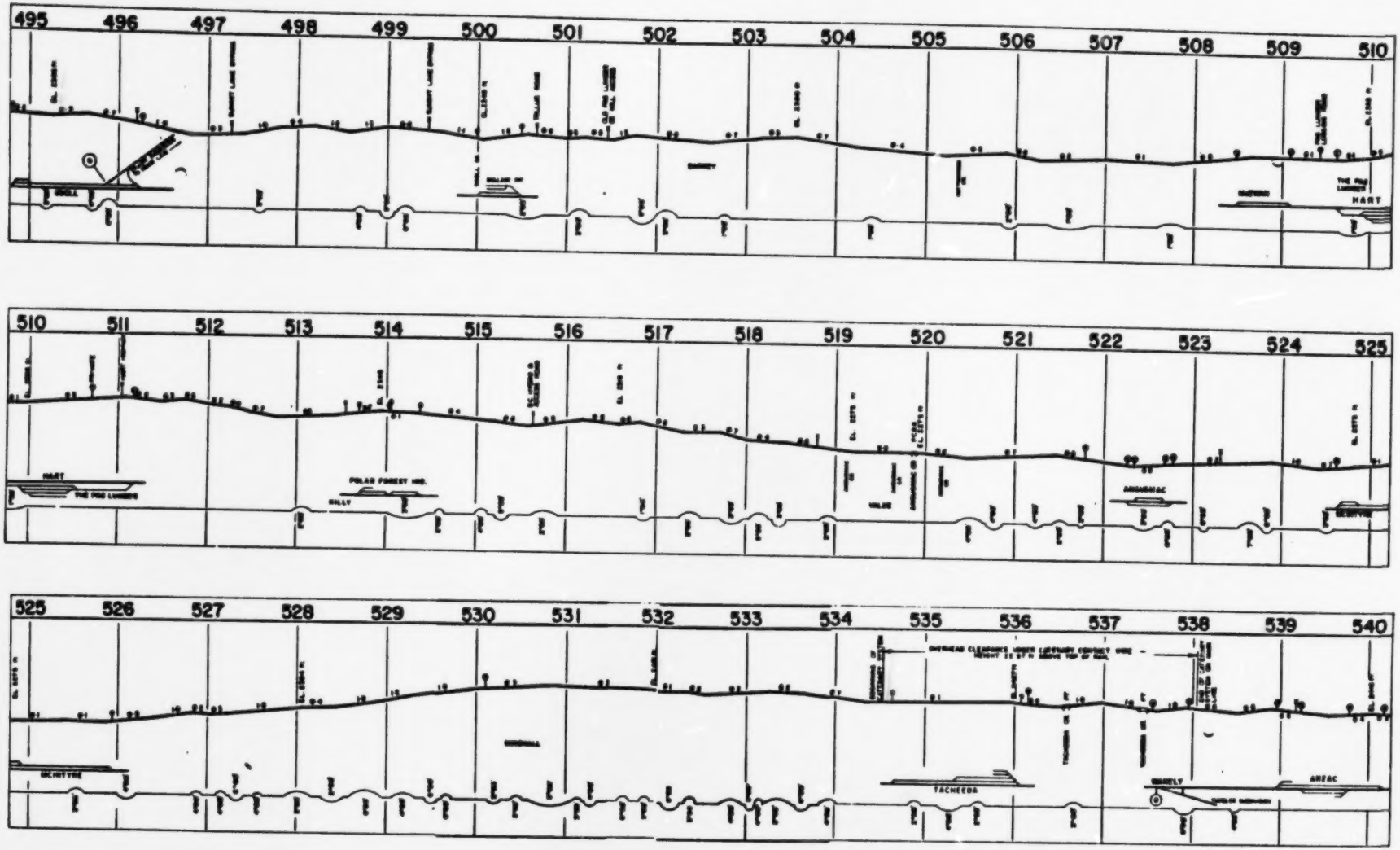
PRINCE GEORGE INDUSTRIAL PARK & CLASSIFICATION YARD
465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480
PRINCE GEORGE MIDDLE YARD
PRINCE GEORGE BRIDGE YARD
FRASERVIEW
480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495

p2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510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525
HART
POLAR FOREST MID.
ARGENTINE
525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540
MCINTYRE
TACHEEDA
ARTAC

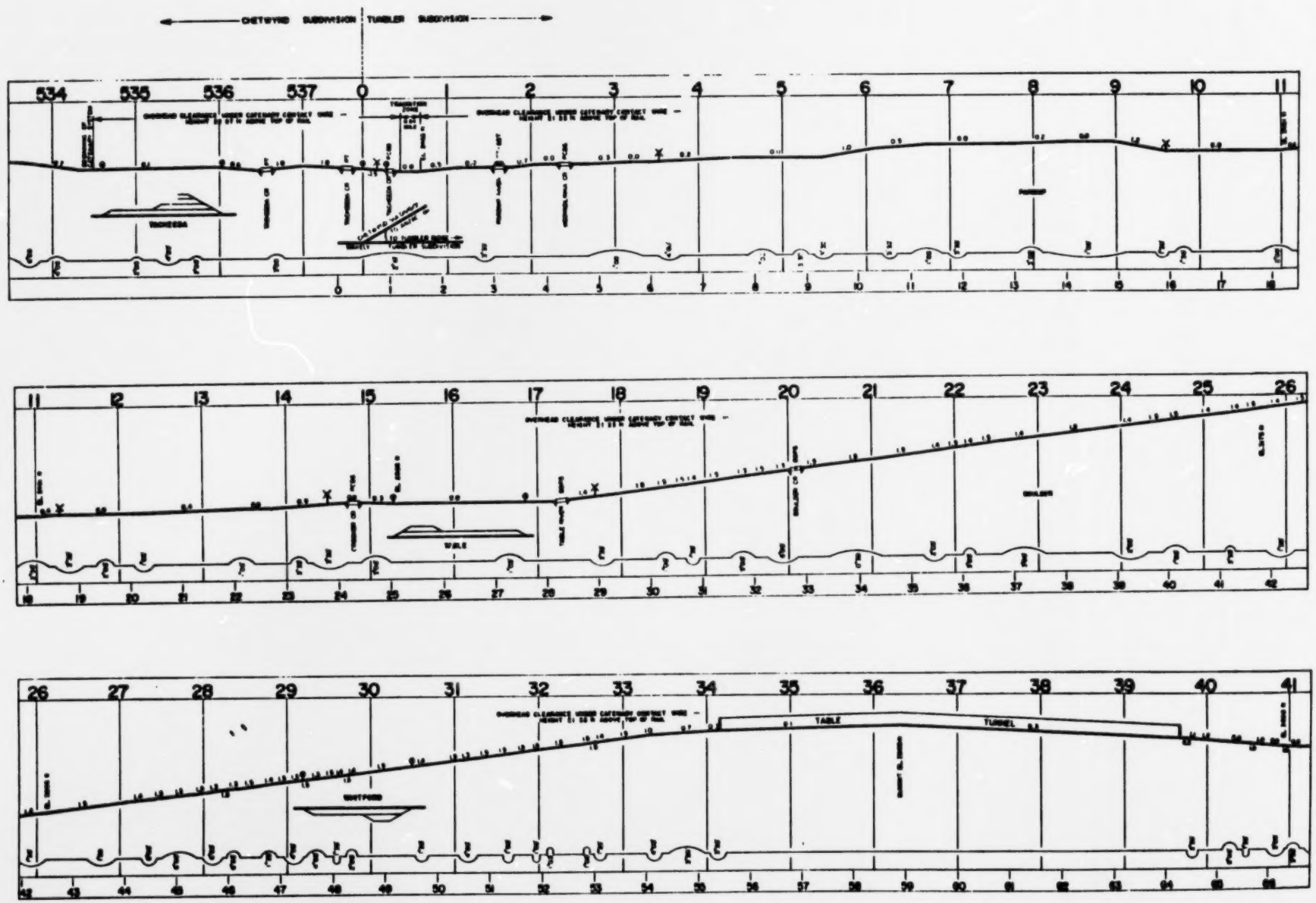
CHETWYND SUBDIVISION
TUMBLER SUBDIVISION
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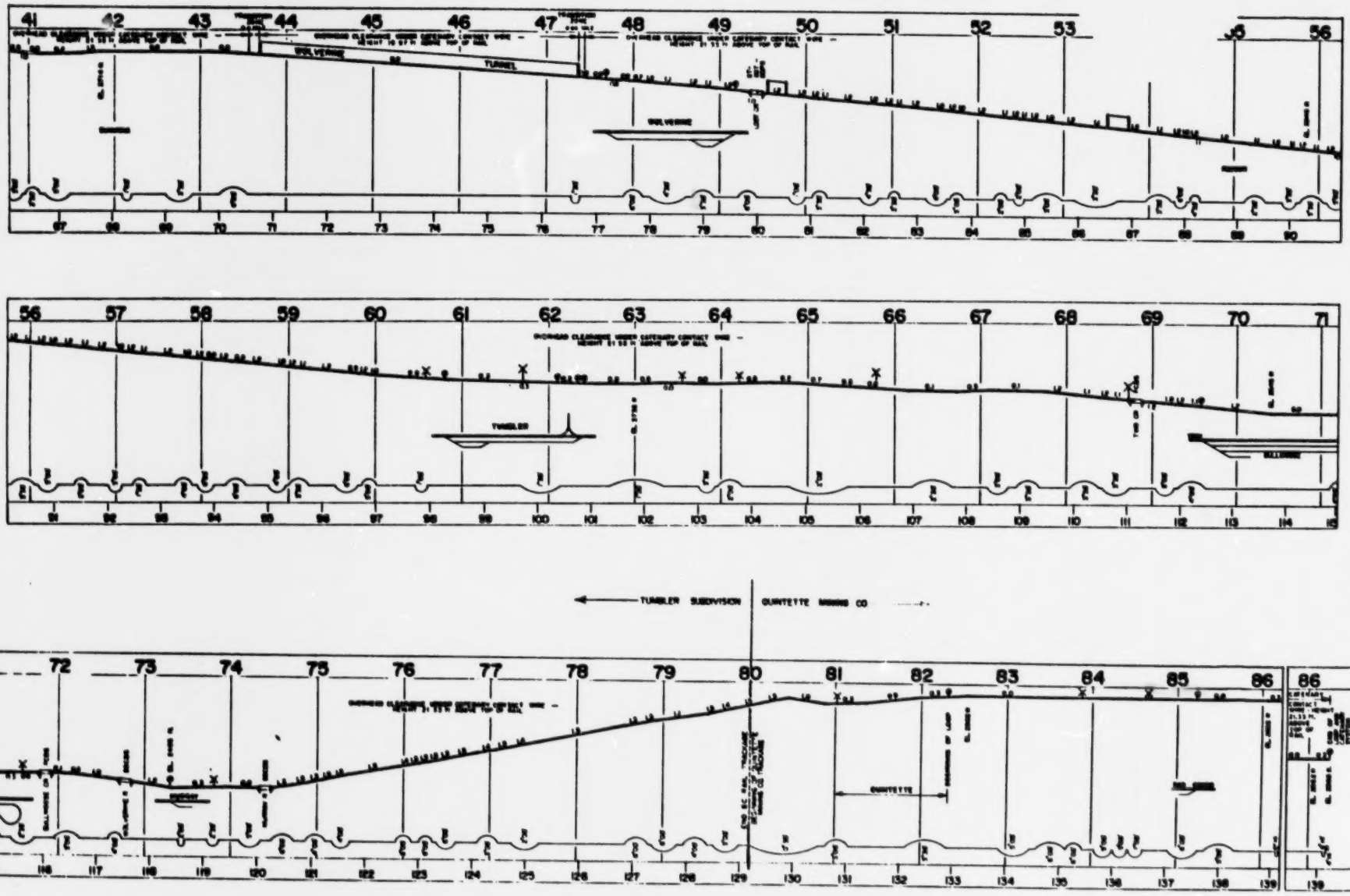
TABLE
TUNNEL



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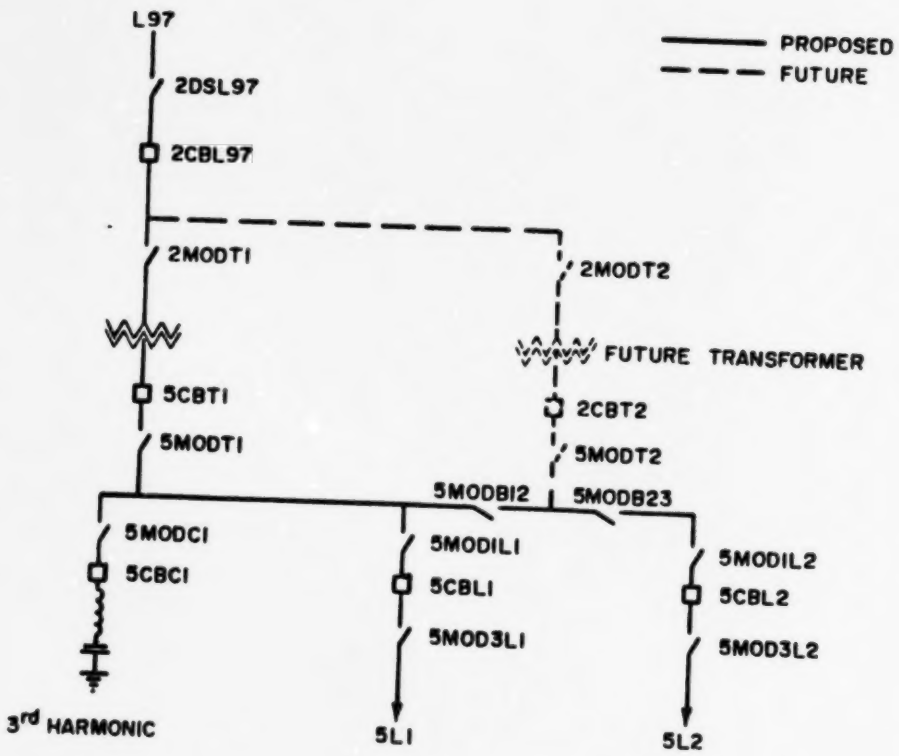


FIG. 3
SINGLE LINE DIAGRAM OF
PROPOSED SALMON VALLEY
230-50kV SUBSTATION (mile 484)

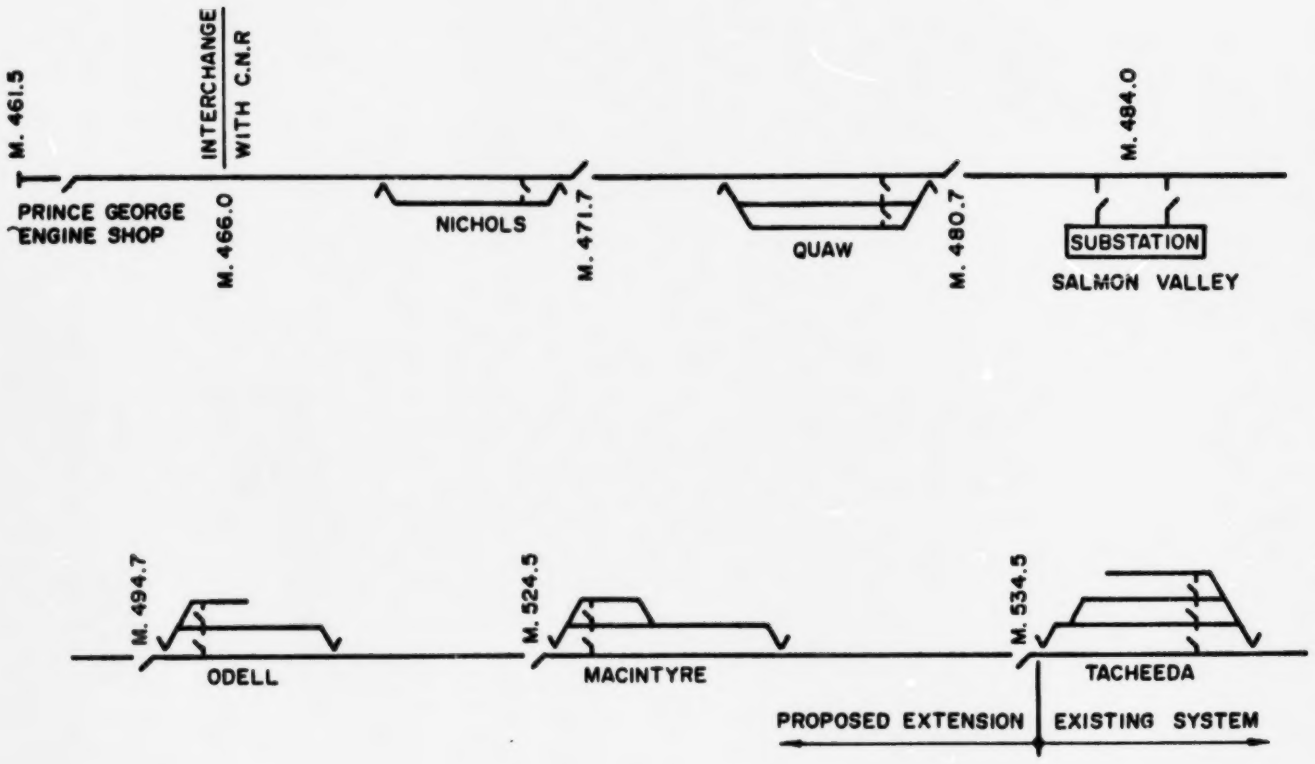
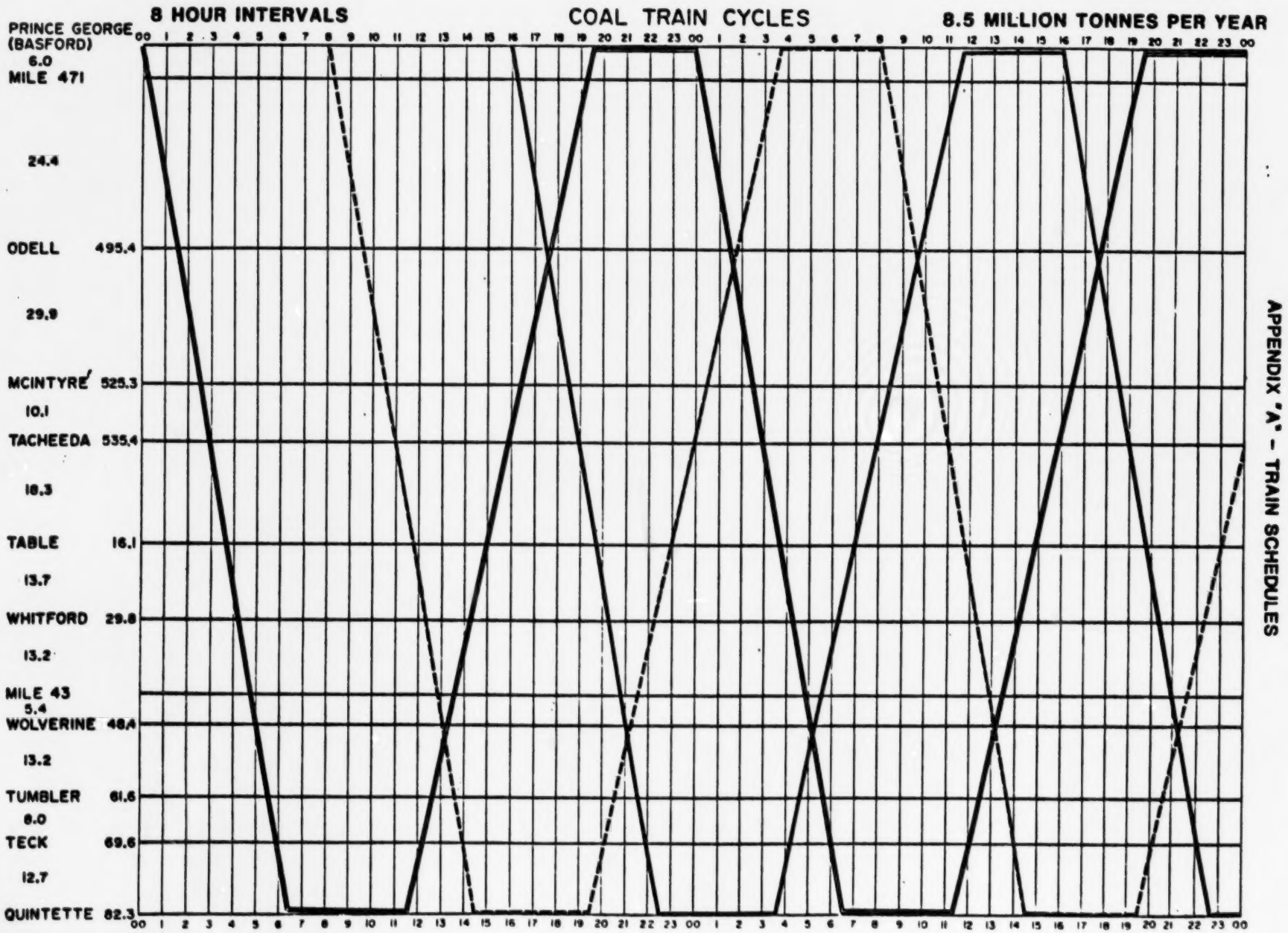
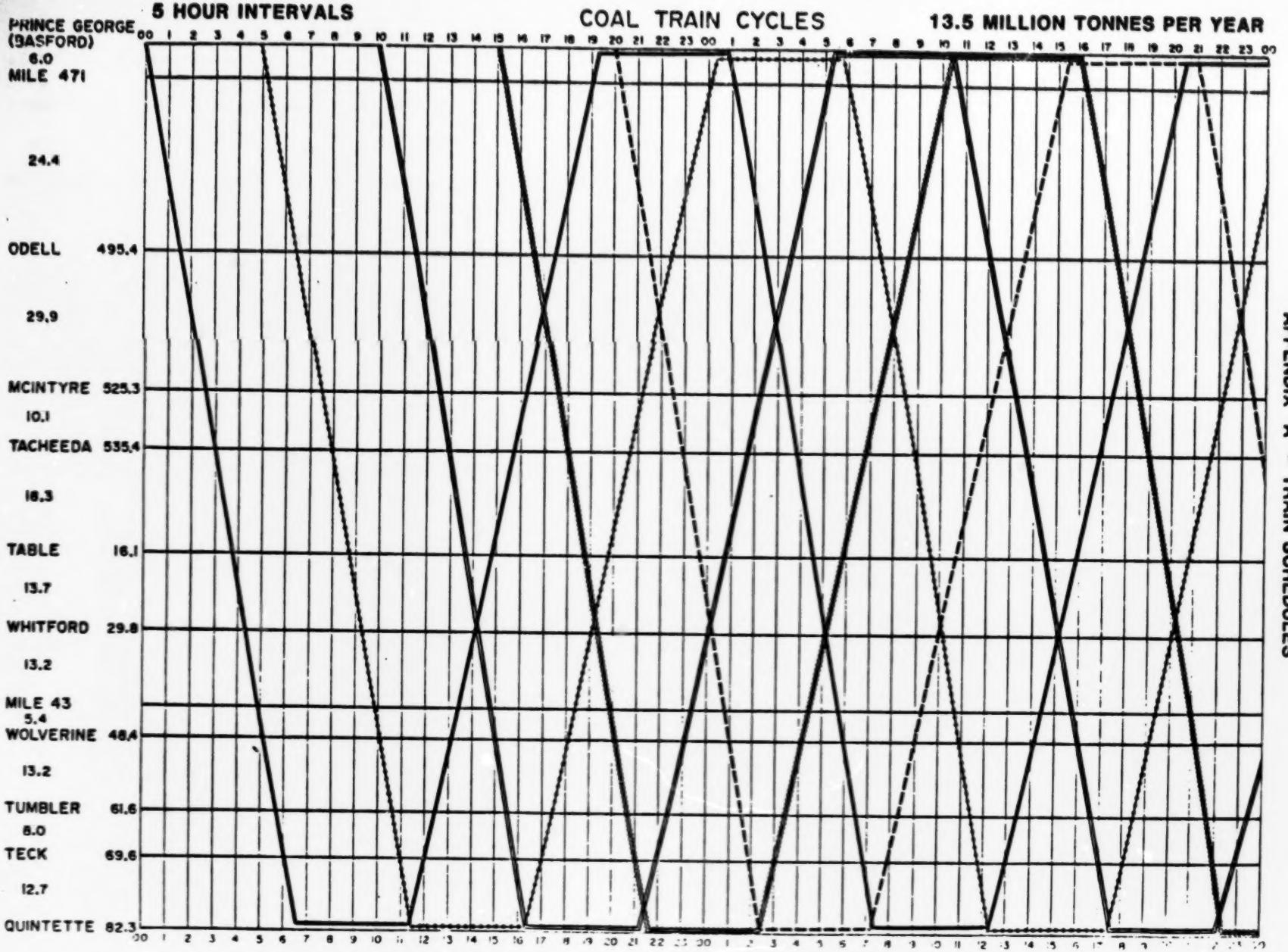


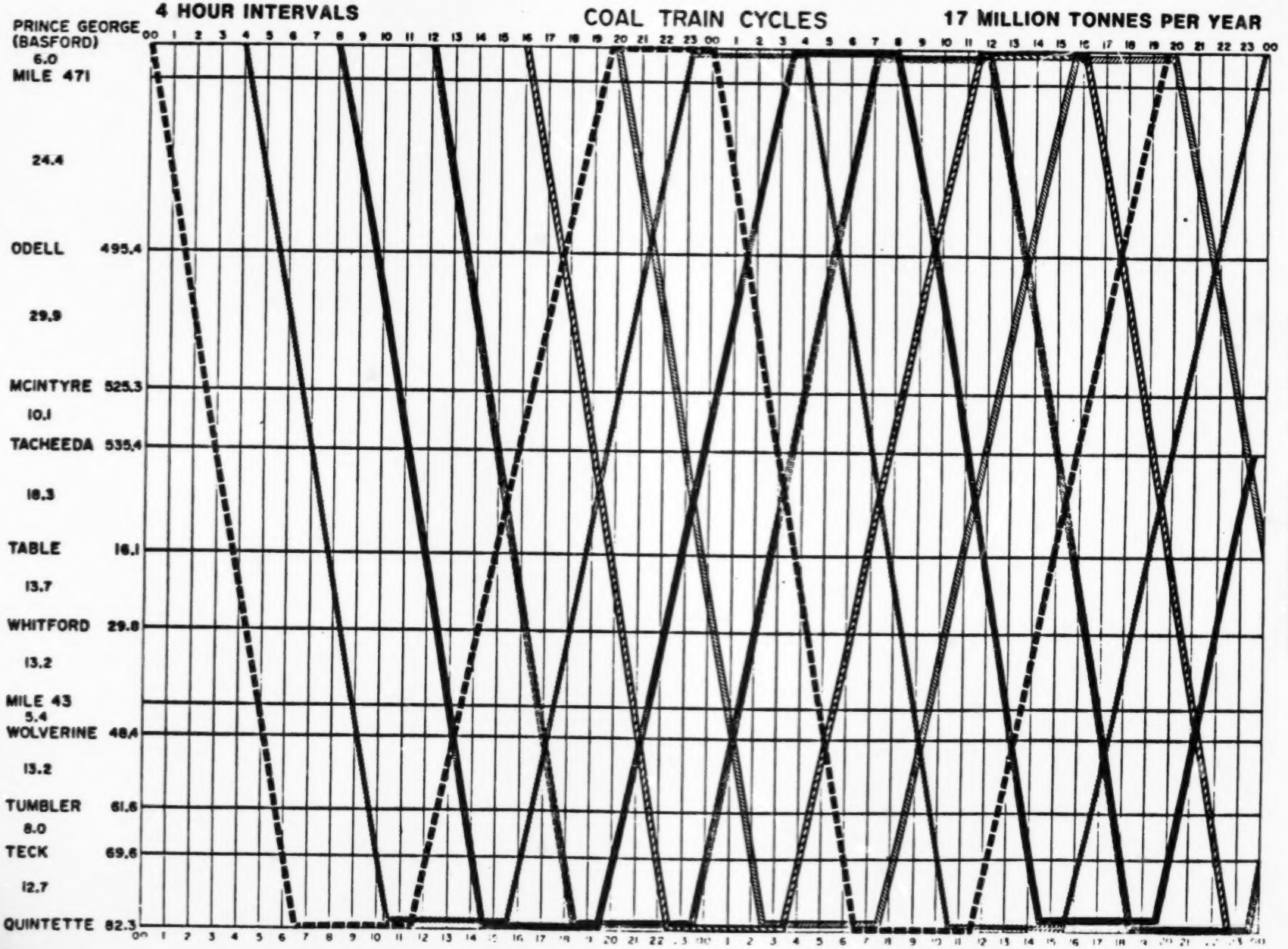
FIG. 4
SINGLE LINE DIAGRAM OF PROPOSED ELECTRIFICATION OF B.C. RAIL MAINLINE FROM PRINCE GEORGE TO TACHEEDA



APPENDIX 'A' – TRAIN SCHEDULES



APPENDIX "A" - TRAIN SCHEDULES


4 HOUR INTERVALS
COAL TRAIN CYCLES
17 MILLION TONNES PER YEAR
PRINCE GEORGE (BASFORD)
6.0
MILE 471
24.4
ODELL 495.4
29.9
MCINTYRE 525.3
10.1
TACHEEDA 535.4
18.3
TABLE 16.1
13.7
WHITFORD 29.8
13.2
MILE 43
5.4
WOLVERINE 48.4
13.2
TUMBLER 61.6
8.0
TECK 69.6
12.7
QUINTETTE 82.3
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APPENDIX B

B1.0 MOTIVE POWER - CAPITAL, OPERATING AND MAINTENANCE COSTS

B1.1 Number of Locomotives Required

The current agreement between BC Rail and CN Rail for the movement of coal between the mine sites and the coal port at Prince Rupert states that:

1. BC Rail is responsible for the supply of 25% of all head end motive power required for the combined BC Rail/ CN Rail unit coal train operation between the mine sites and Prince Rupert.

2. CN Rail is responsible for the supply of 75% of the head end motive power required.

3. BC Rail is responsible for the supply of all pusher power required on BC Rail property.

4. BC Rail pays CN Rail $1.89 per locomotive kilometre for the distance travelled on BC Rail property between Prince George and Table.

5. BC Rail pays for all fuel used on BC Rail property.

6. Two 6000 hp electric locomotives will be considered equivalent to three 3000 hp diesel-electric locomotives.

7. A "set" of head end motive power is comprised of 3 x 3000 hp diesel-electric units (or 2 x 6000 hp electric locomotives).

B1.2 Motive Power Required to Move 8.5 Million Tonnes of Coal Per Year

The schedule (fig. A1, Appendix A) to move 8.5 million tonnes of coal per year requires 9 "sets" of head end motive power for the combined BC Rail/CN Rail. This would require 27 x 3000 hp diesel-electric units (3 x 3000 hp units per set). It was agreed that 4 x 3000 hp units would be provided as system spares for maintenance rotation for a total of 31 diesel-electric units. BC Rail would be obligated to provide 8 x 3000 hp diesel-electric (25% of 31 units as detailed in Section B1.1). In addition, BC Rail would require one set of pusher power. Therefore, BC Rail would be contractually responsible for the supply of a total of 11 x 3000 hp diesel-electric units or 7 x 6000 hp electric locomotives. All these units would be required to move the coal traffic on the Tumbler Subdivision. Consequently, CN Rail is contractually obligated to provide all motive power to move the traffic between Tacheeda and Prince Rupert. BC Rail supplied 7 x 6000 hp electric locomotives to fulfill its obligations.

The extension of electrified operation from Tacheeda to Prince George would require the purchase of 4 x 6000 hp additional electric locomotives (two sets of 2 x 6000 hp). The net result would be that BC Rail would exceed its contractual obligations by providing 2 extra sets of power and CN Rail would be relieved of its obligation to provide two sets of power (6 diesel-electric locomotives).

This analysis assumes that CN Rail will reimburse BC Rail on a one-to-one basis for the electric locomotives supplied by BC Rail.

B1.3 Motive Power Required to Move 13.5 Million Tonnes of Coal Per Year

The schedule (fig. A2, Appendix A) to move 13.5 million tonnes per year from the mine sites to Ridley Island would require:

14 sets of head end power = 42 diesel-electric units
+ 5 spare units
Total required = 47 x 3000 hp diesel-electric units

BC Rail's contribution (at 25%) = 12 x 3000 hp diesel-electric units
One pusher set = 3 units
BC Rail's commitment = 15 x 3000 hp diesel-electric units

BC Rail is contractually obligated to provide 15 x 3000 hp diesel-electric units or 10 x 6000 hp electric locomotives. All these units would be required to move the traffic on the Tumbler Subdivision. CN Rail would be contractually obligated to provide all motive power to move the traffic between Tacheeda and Prince Rupert.

If the Tacheeda to Prince George section were electrified, an additional 2 sets of electric locomotives (for a fleet total of 11 electric locomotives) would be required and the 2 sets of 3 x 3000 hp diesel-electric locomotives that would be CN Rail's obligation to supply, would be released.

B1.4 Motive Power Required to Move 17 Million Tonnes of Coal Per Year

The schedule (fig. A3, Appendix A) to move 17.0 million tonnes per year would require the same number of locomotive sets as 13.5 million tonnes per year due to better utilization.

B2.0 DIESEL-ELECTRIC LOCOMOTIVE OPERATING AND MAINTENANCE COSTS

Currently BC Rail pays CN Rail $1.89 per locomotive kilometre to cover maintenance costs for each kilometre the CN Rail supplied diesel-electric locomotive runs on BC Rail property between Prince George and Table.

Based on a round trip of 225 km and three 3000 hp diesel-electric units per train between Prince George and Tacheeda, BC Rail pays CN Rail $1,275 per round trip.

B3.0 DIESEL FUEL COSTS

Diesel fuel costs for the Tacheeda to Prince George portion are based on the actual fuels costs charged BC Rail by CN Rail.

During the months of August and September, 1985, 347,467 litres of diesel fuel was consumed by 172 locomotives associated with the coal movement between Tacheeda and Prince George for a total charge of $127,475.22.

$$\text{cost of diesel fuel} = \frac{\$127,475.22}{347,467 \text{ litres}} = \$0.3668/\text{litre}$$

$$\text{diesel fuel consumed per trip} = \frac{347,467 \text{ litres}}{172 \text{ locomotives}} \times \frac{3 \text{ locomotives}}{\text{trip}} = 6,060 \text{ litres}$$

cost of diesel fuel per trip
6,060 litres x $0.3668/litre = $2,223/trip

B4.0 ADDITIONAL LABOUR COSTS PER TRIP

It is presently necessary to exchange the electric locomotives for diesel-electric units at Tacheeda when southbound and vice versa when northbound.

Under ideal conditions, each power swap takes a minimum of 30 minutes to complete. Based on a four-man train crew, the minimum cost savings per trip that will be realized by eliminating the diesel-electric/electric locomotive swap is:

$35 per swap x 2 swaps per trip = $70 per trip

TABLE B1
Operating Labour Savings
All Electric Operation

Million Tonnes of Coal Per Year	Number of Trips Per Year	Minimum Cost Savings Per Year
8.5	953	$66,700
13.5	1,514	$105,980
17.0	1,906	$133,420

It should be noted that the 30 minutes per power swap is based on ideal conditions. Under less than ideal conditions the time required for the power swap will be greater.

APPENDIX C

C1.0 ELECTRIC LOCOMOTIVE OPERATING AND MAINTENANCE COSTS

C1.1 Energy

The TPC model (see Appendix E) shows that 13.2 megawatt hours of energy must be expended to transport a coal train on a round trip between Prince George and Tacheeda. Based on the current price of $0.02463 per kilowatt hour, this equates to:

$$\frac{13.2 \text{ megawatt hours}}{\text{trip}} \times \frac{\$0.02463}{\text{kilowatt hour}} \times \frac{1000 \text{ kilowatt hours}}{\text{megawatt hour}}$$

= $325 of electric energy per trip

C1.2 Demand

The TPC model shows that, on the Prince George to Tacheeda section, an empty coal train produces a 30 minute demand of 2.6 megawatt hours, and a loaded train produces a demand of 2.9 megawatt hours. To maintain the current schedule, an empty and loaded train must operate simultaneously. The worst case of coincident demands is considered. Based on the current rate of $5.50 per month per kilowatt hour demand, the annual demand charge would be:

$$5.5 \text{ megawatt hours} \times \frac{12 \text{ months}}{\text{year}} \times \frac{\$5.50}{\text{kilowatt hour}} \times \frac{1000 \text{ kilowatt hours}}{\text{megawatt hour}}$$

= $363,000 per year

C1.3 Maintenance Costs

The anticipated annual maintenance cost per electric locomotive is $88,800 (see Table C1) and is relatively independent of unit loading until approximately 240 kilometers per year per locomotive is exceeded. Until 240 kilometers per year is reached, the majority of maintenance is calendar dictated (i.e. daily, monthly, yearly inspection and maintenance program).

The anticipated annual mileage per electric locomotive for the Prince George to Quintette section is:

8.5 million tonnes per year	71,000 kilometers per year
13.5 million tonnes per year	165,000 kilometers per year
17.0 million tonnes per year	208,000 kilometers per year

TABLE C1

6000 H.P. ELECTRIC LOCOMOTIVE MAINTENANCE COSTS

CLASS OF INSPECTION	FREQUENCY	LABOUR	MATERIAL	TOTAL	YEARLY	% OF DIESEL COSTS
Trip Inspection	Daily	45	45	90	$32,850	75%
Datal Inspection	45 Days	570	60	630	5,000	48%
Annual Inspection	Yearly	1,000	60	1,060	1,060	51%
Air Brake Schedule	6-12-24 Months	250	730	980	980	100%
Inspections Total					39,890	70%
Repair & Service (Diesel	Fleet Averaged)				45,400	66%
Backshop	10 Years (Wiring & Paint)				3,500	8%
Per Unit	Yearly Total - Repair Service, O'haul				48,900	64%
Per Unit	Total Annual Maintenance				$88,780	50%
On Basis of Horsepower						25%

APPENDIX D

D1.0 FIXED PLANT FACILITIES ELECTRIFICATION PRINCE GEORGE - TACHEEDA

D1.1 Traction Feeder Substation

D1.1.1 Location

B.C. Hydro has two 230 kV substations in the vicinity of the proposed Prince George - Tacheeda electrification extension:

1. Williston Substation - located east of Prince George and approximately 14.5 km from the south end of Bridge Yard.

2. Salmon Valley Substation - located near Mile 484 and approximately 3 km from trackside.

A 230 kV transmission line, 2L97, feeds Salmon Valley Substation from Williston Substation. This transmission line parallels BC Rail's line between Prince George and Salmon Valley and crosses the railway at Mile 477.5 and Mile 484 (see fig. 1).

A supply from either substation will require that B.C. Hydro install a 230 kV breaker position to service the traction substation and will also require a feeder line between the traction substation and the trackside catenary supply point.

The costs associated with using either substation to directly supply the traction substation are estimated at:

	Williston Substation	Salmon Valley Substation
Complete 230 kV ring position	$800,000	$800,000
Length of feeder line required	14.5 km	3 km
Construct 50 kV feeder line between substation and trackside (@ $50,000/km)	$725,000	$150,000

These costs do not include land acquisition or clearing costs.

A third alternative is to directly tap the 230 kV transmission line at a convenient point. If line 2L97 were tapped where the transmission line crosses the railway, the requirement for a feeder line would be eliminated. The

requirement for the additional 230 kV breaker arrangement at the B.C. Hydro substation would also be eliminated.

A simple 230 kV tap with an air disconnect is proposed at Mile 484. All fault detection clearing in the BC Rail system would be performed within the traction feeder station.

It is believed that this configuration could be implemented without jeopardizing the security of B.C. Hydro's line 2L97. The tap would add approximately 100 m to the present 37 km length of line 2L97. It is anticipated that the entire 230kV tap could be installed for $250,000. It should be noted that B.C. Hydro has not been formally approached with the proposal of a direct tap from line 2L97.

Voltage profile and harmonic studies (see Appendices F and G) indicate that this alternative will provide satisfactory service. A direct connection to the 230 kV line 2L97 at Mile 484 is the most cost effective alternative and is used for the cost-benefit evaluation.

D1.1.2 Configuration

A 230/50 kV traction feeder substation with two 50 kV feeder positions and a single 25/33 MVA transformer is proposed. The existing traction feeder station at Tumbler Ridge has two 25/33 MVA transformers. The maximum Tumbler Ridge load is 25 MVA and could be easily carried by one transformer. It is proposed to use one of the Tumbler Ridge substation transformers as a spare for both Tumbler Ridge and the Mile 484 substation. In the unlikely event of serious damage to the single transformer installed to feed the Prince George to Tacheeda section, one of the Tumbler Ridge transformers could be relocated and placed in service within 2 weeks. The installation of the second transformer positions would add approximately $900,000 to the cost of the substation.

Due to the low power factor of the GF6C locomotives (see fig. E3, Appendix E), a shunt capacitor will be tuned with a tapped air-core series reactor to control harmonic distortion caused by the GF6C locomotives.

D1.1.3 Cost

The cost of providing a 230/50 kV substation with two 50 kV feeder positions, one 25/33 MVA transformer, power factor correcting capacitors, is estimated at:

Material	$1,800,000
Social Service Tax	126,000
Labour	1,400,000
Total	$3,326,000
Hydro Connection	250,000
Total Substation	$3,576,000

Land acquisition costs are not included.

D1.2 Harmonic Filtering

The EMTP model indicates that a damping filter is required to prevent harmful overvoltages (see Appendix F).

The cost of providing the harmonic filtering is estimated at:

Equipment and Material	$125,000
Social Service Tax	9,000
Installation	125,000
Total	$259,000

Land acquisition costs are not included.

D1.3 Overhead Contact System

D1.3.1 Design

For the purposes of this study it is assumed that electrification of the BC Rail mainline would be extended 119 km from Tacheeda to the locomotive shop at Prince George. It also assumes that the sidings at McIntyre, Odell and Quaw would be electrified and provisions are included to electrify the new 2,135 meter Nichols siding just north of the Bridge Yard.

Sectionalizing motor-operated disconnect switches would be installed at each siding and would be remotely operated from the North Vancouver control centre (see fig. 4).

An allowance of $125,000 has been made for modifications to signalized road crossings that may be required as a result of the use of the rail as a return conductor in Electrified Territory.

It is assumed an identical design to that installed on the Tumbler Ridge Branch Line will be used with minor modifications to utilize more North American produced hardware. No significant cost savings are anticipated as a result of the changes.

Voltage calculations indicate the feeder wire may be eliminated from the substation to Bridge Yard at a cost saving of $100,000. This cost saving is reflected in the capital costs shown in Section 1.3.2.

1.3.2 Capital Costs

The cost of providing 119 km of catenary system, including sidings at Bridge Yard, Odell, McIntyre and Quaw, is estimated at:

Material	$5,730,000
Social Service Tax	401,000
Installation	2,695,000
Total	$8,826,000

It is anticipated that an additional $150,000 will be required to effectively ground 35 road crossings between Prince George and Tacheeda for a total capital investment of $8,976,000.

Road crossing clearance portals have not been included in the estimates. The lowest part of the catenary will be installed at 7.0 m above top of rail.

1.3.3 Maintenance

It is expected that a single three-man crew plus one foreman would be required to maintain the catenary system, substation and harmonic filter station. The annual maintenance costs are estimated to be:

Labour	$202,000
Equipment	-
Tools and Materials	33,000
Total	$235,000/year

This figure does not include the supply of offices, lunchrooms or living accommodations. It is assumed that the existing office and lunchroom facilities would be adequate for the additional crew. It is also assumed that the crew would be based at Prince George and that no living accommodations would be required.

It is expected that the maintenance costs would be independent of the number of train movements. Increased train movements may limit track access and careful scheduling of maintenance will be required.

TABLE 3
COST SUMMARY
PRINCE GEORGE TO TACHEEDA UNIT COAL TRAIN OPERATION

	8.5 Million Tonnes Per Year (953 trips per year)		13.5 Million Tonnes Per Year (1514 trips per year)		17.0 Million Tonnes Per Year (1906 trips per year)	
	Electric	Diesel	Electric	Diesel	Electric	Diesel
Capital Costs						
Electric locomotives ($2.854 million each)	11,416,000		11,416,000		11,416,000	
CN reimbursement	<6,800,000>		<6,800,000>		<6,800,000>	
Power supply & catenary	16,170,000		16,170,000		16,170,000	
Construction interest	371,000		371,000		371,000	
Total Capital	21,157,000		21,157,000		21,157,000	
Maintenance (Annual)						
Catenary & power supply	235,000		235,000		235,000	
Electric locomotives	355,000		355,000		355,000	
Operating (Annual)						
Diesel fuel		2,079,000		3,304,000		4,159,000
Payment to CN for diesel-electric maintenance ($1,275/trip)		1,216,000		1,932,000		2,432,000
Power swap at Tacheeda ($70/trip)		67,000		106,000		133,000
Electrical energy ($325/trip)	310,000		492,000		619,000	
Electrical demand ($363,000/year)	363,000		363,000		363,000	
Total Annual Maintenance & Operating	1,263,000	3,362,000	1,445,000	5,342,000	1,572,000	6,724,000

APPENDIX E

E1.0 TRAIN PERFORMANCE CALCULATOR MODEL

The GF6C electric locomotives supplied by General Motors of Canada underwent extensive performance testing on the Tumbler Ridge Branch Line. The results of the Tractive Effort vs Speed (fig. E1), Efficiency vs Speed (fig. E2), and Power Factor vs Speed (fig. E3) tests were incorporated into the TPC model. The model was then run using the track profile of the Tumbler Ridge Branch Line (fig. 2). The results (fig. E4) were compared with the power (MW vs Time) profile of an actual loaded coal train operating between Quintette and Tacheeda (fig. E5) as recorded by the chart recorders in the Tumbler Substation. The model closely agreed with the actual results.

The TPC model was used to evaluate:

1) a single loaded coal train southbound between Tacheeda and Prince George (fig. E6).

2) a single empty coal train northbound between Tacheeda and Prince George (fig. E7).

3) a single loaded coal train southbound between Quintette and Tacheeda (fig. E4).

4) a single empty coal train northbound between Tacheeda and Quintette (fig. E8).

The results are shown in Table E1.

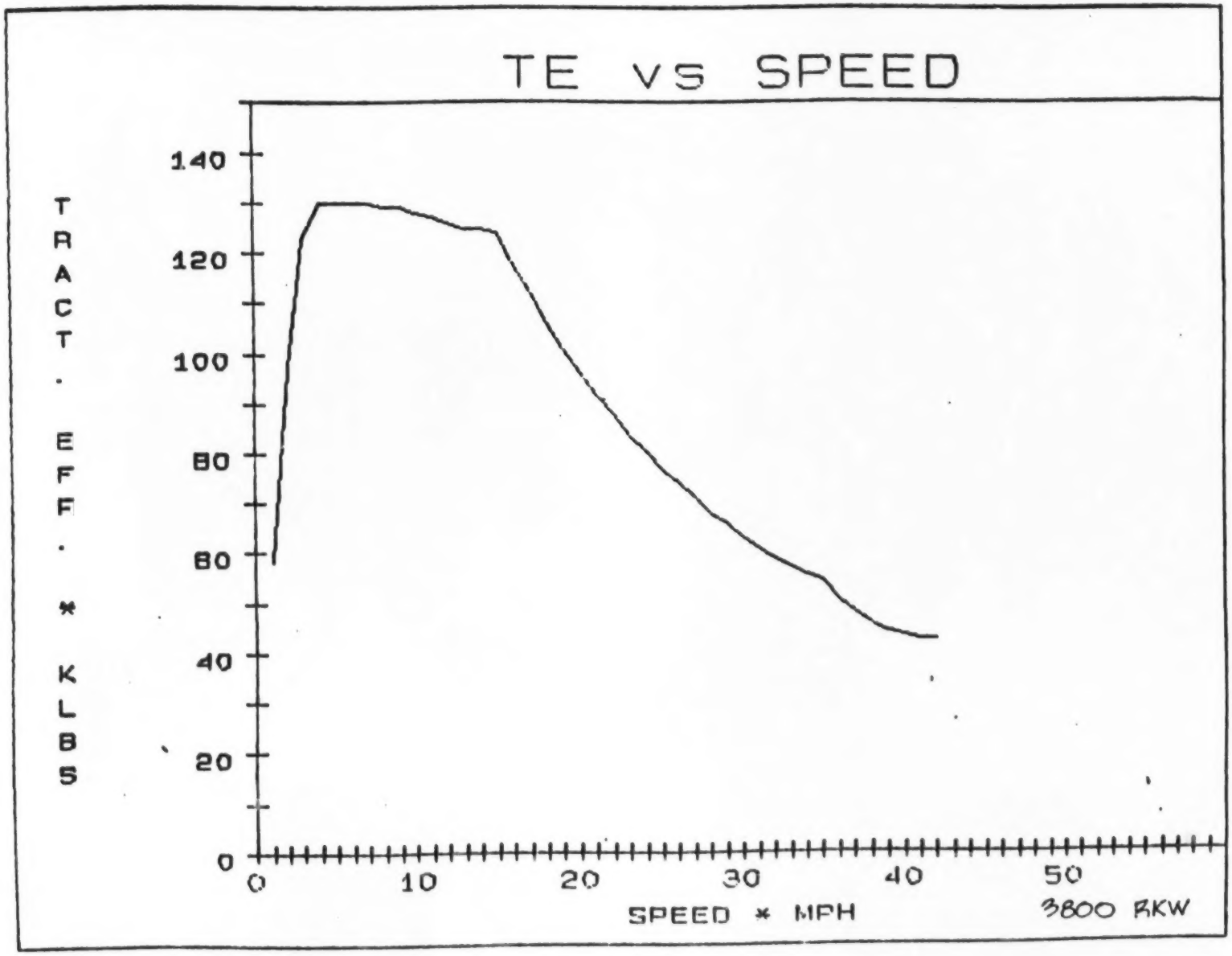
TABLE E1
Results of TPC Model

	Energy Consumed (KWhr)	Max. 30 min. Demand (KWhr)
Loaded Train Tacheeda - Prince George	7,200	2,900
Empty Train Prince George - Tacheeda	6,000	2,600
Loaded Train Quintette - Tacheeda	20,700	8,980
Empty Train Tacheeda - Quintette	7,000	3,580

To maintain the coal train schedules shown in Appendix A (fig. A1, A2, A3), an empty and a loaded train must be operating simultaneously on both the Tacheeda - Prince George and Tacheeda - Tumbler sections. As a result, the worst case of coincident demands is realized. The effects of simultaneous train operation in accordance with the train schedules result in:

1) a combined 30 min. demand of 3,500 KWhr on the Prince George - Tacheeda section.
2) a combined 30 min. demand of 12,560 KWhr on the Tacheeda - Tumbler section.

Since both the sections achieve maximum demand at the same time, no savings are expected by incorporating an integrated demand metering scheme.


TE vs SPEED
TRACT. EFF. * KLBS
140
120
100
80
60
40
20
0
0
10
20
30
40
50
SPEED * MPH
3800 BKW

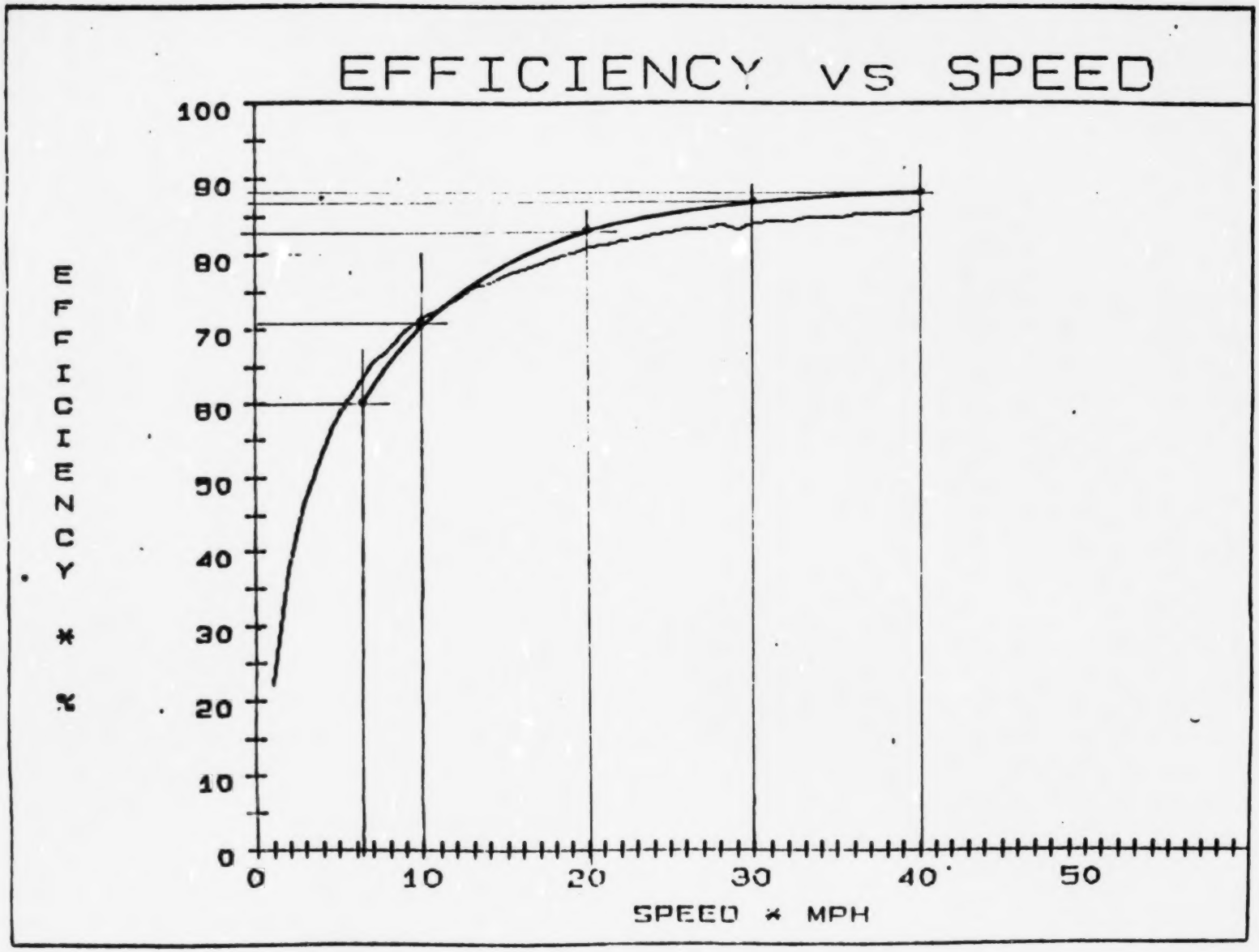

EFFICIENCY vs SPEED
EFFICIENCY * %
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
SPEED * MPH

fig E.2
E-4

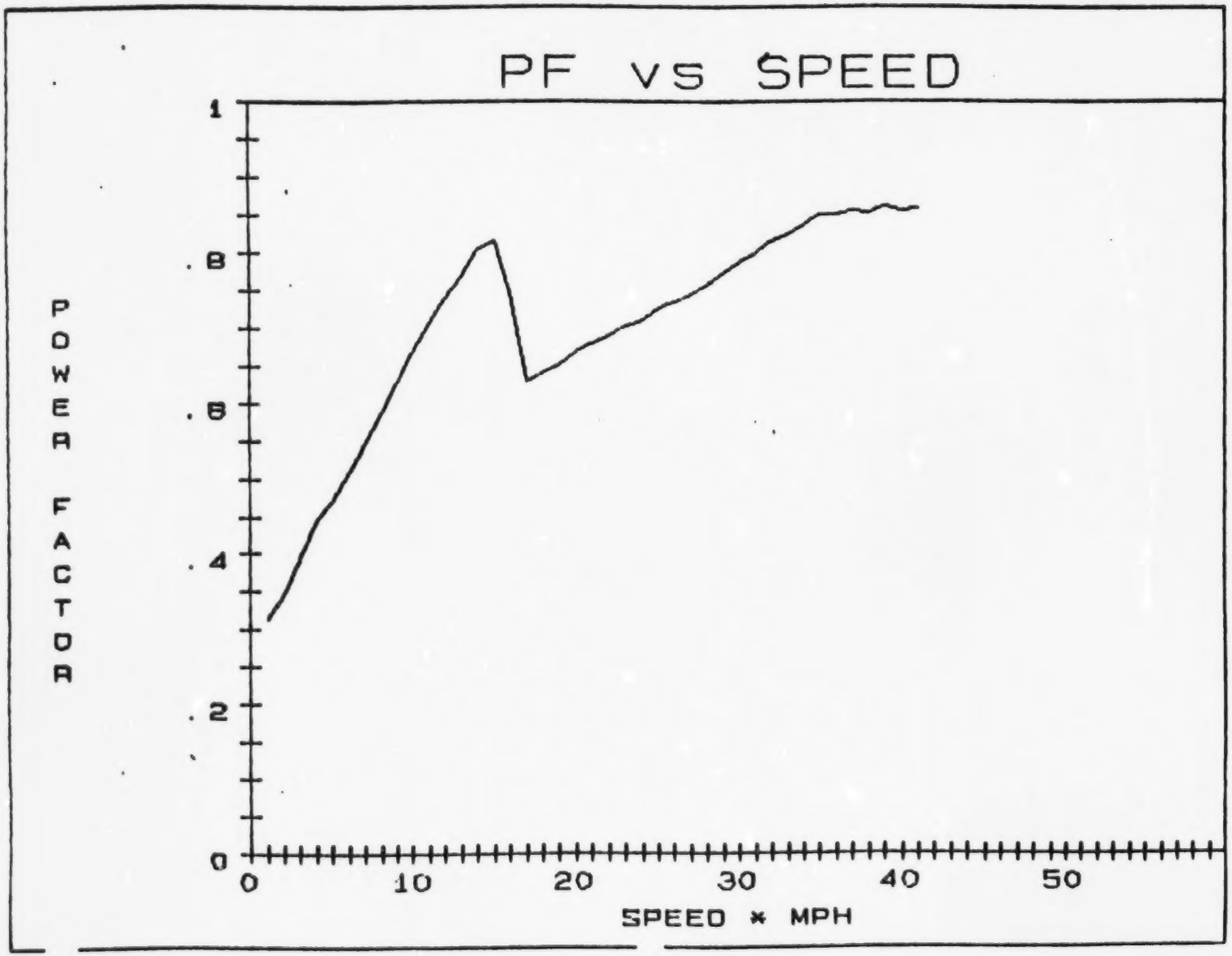


fig E-3
p E-5

B.C. RAIL - Engineering

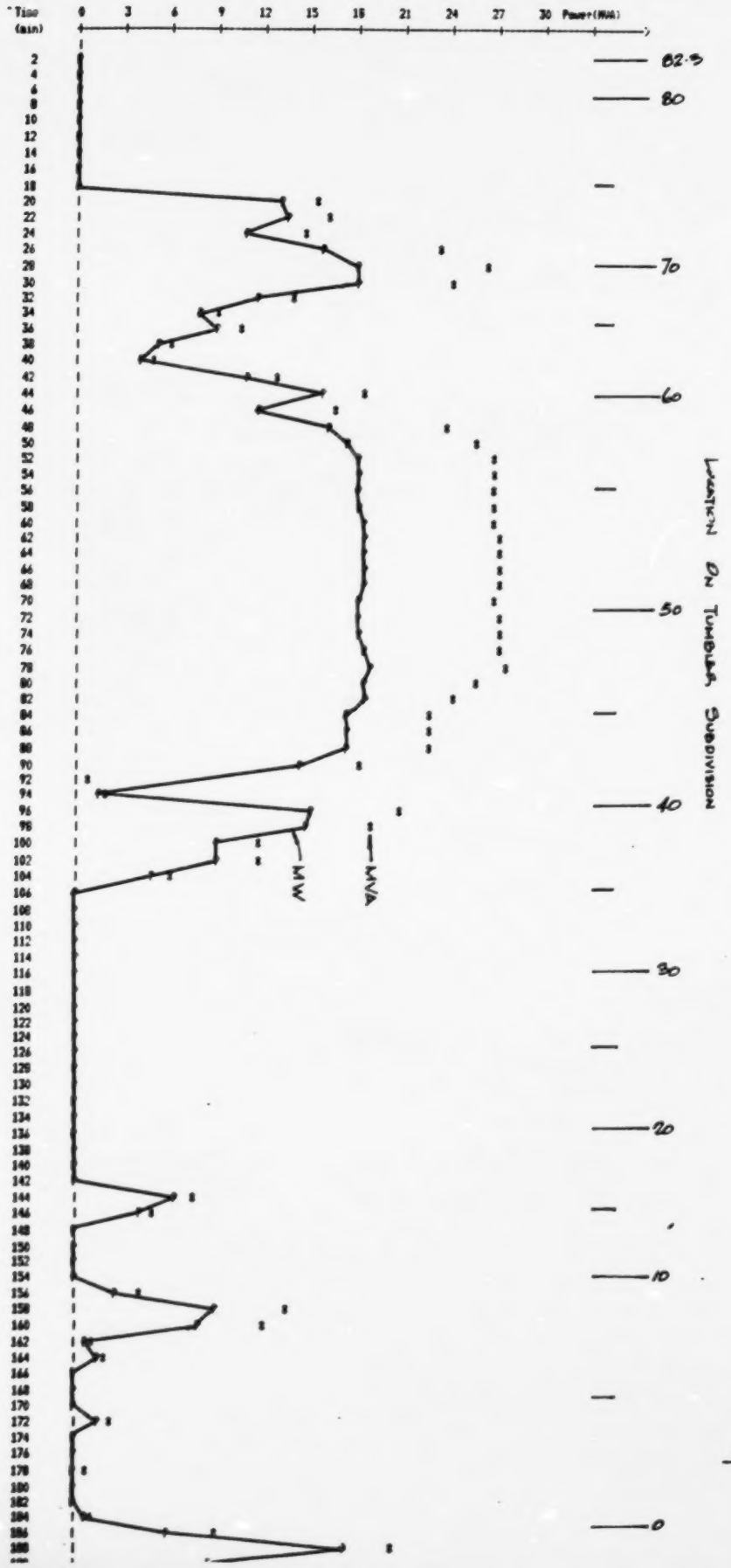


fig. E4

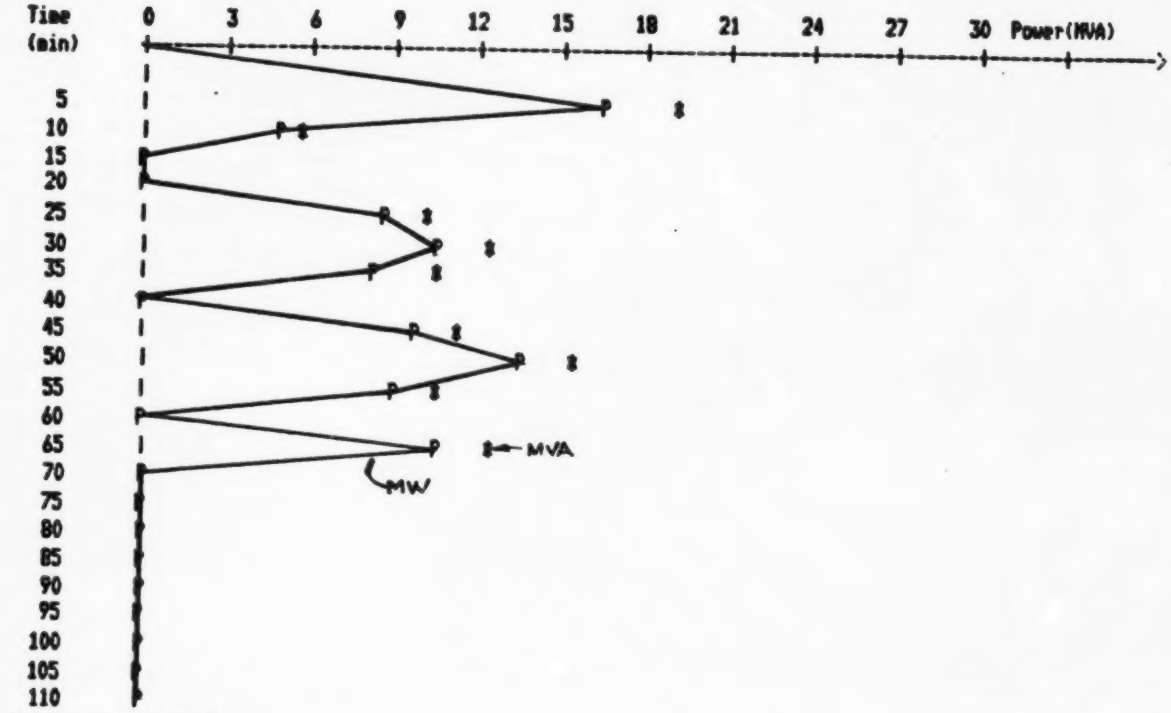
P E-6

Fig. E5 Typical Strip Chart Record of Mega-Watts & Mega-VARS @ L321

85/07/11

COAL TRAIN PERFORMANCE

B.C. RAIL - Engineering



Another Chart? (Y/N):
? Y
Select one of: S = SPEED vs TIME
L = Train LOCATION vs TIME
P = POWER vs TIME
V = VOLTAGE at the Train vs TIME
E = Exit.

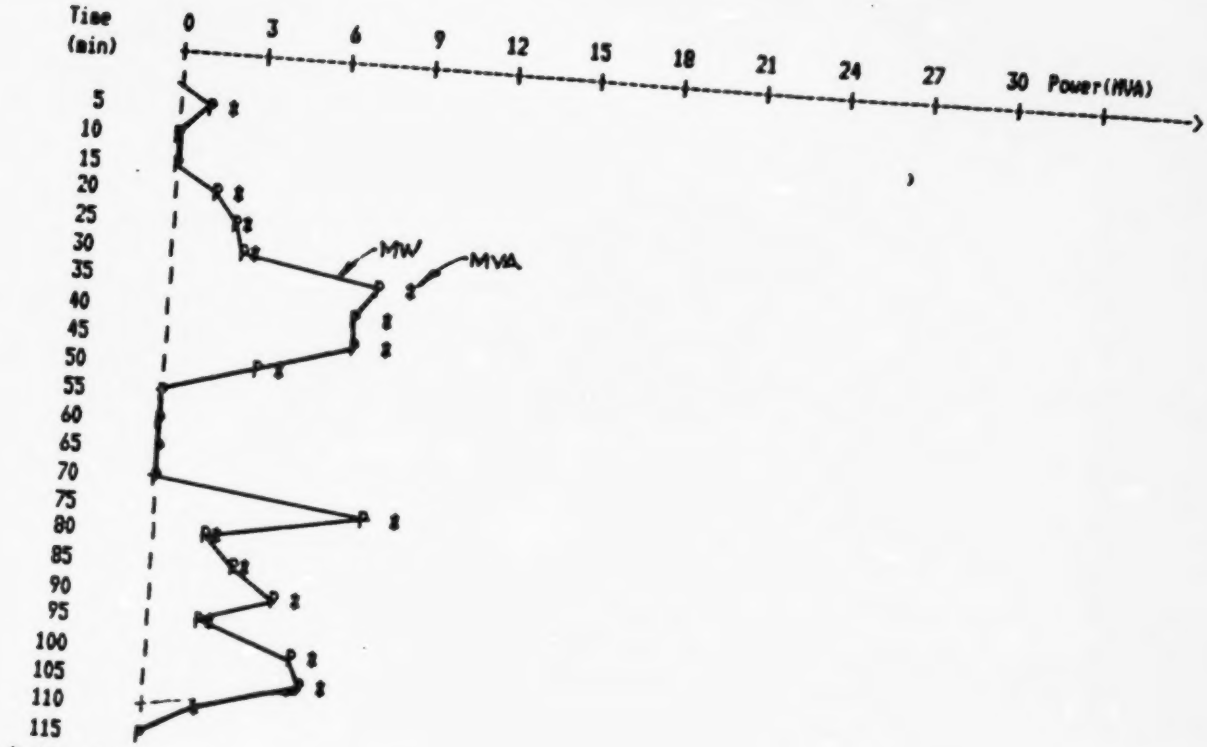
? V

fig E·6
p E-8

85/07/11

COAL TRAIN PERFORMANCE

B.C. RAIL - Engineering



Another Chart? (Y/N):
? Y
Select one of: S = SPEED vs TIME
L = Train LOCATION vs TIME
P = POWER vs TIME
V = VOLTAGE at the Train vs TIME
E = Exit.

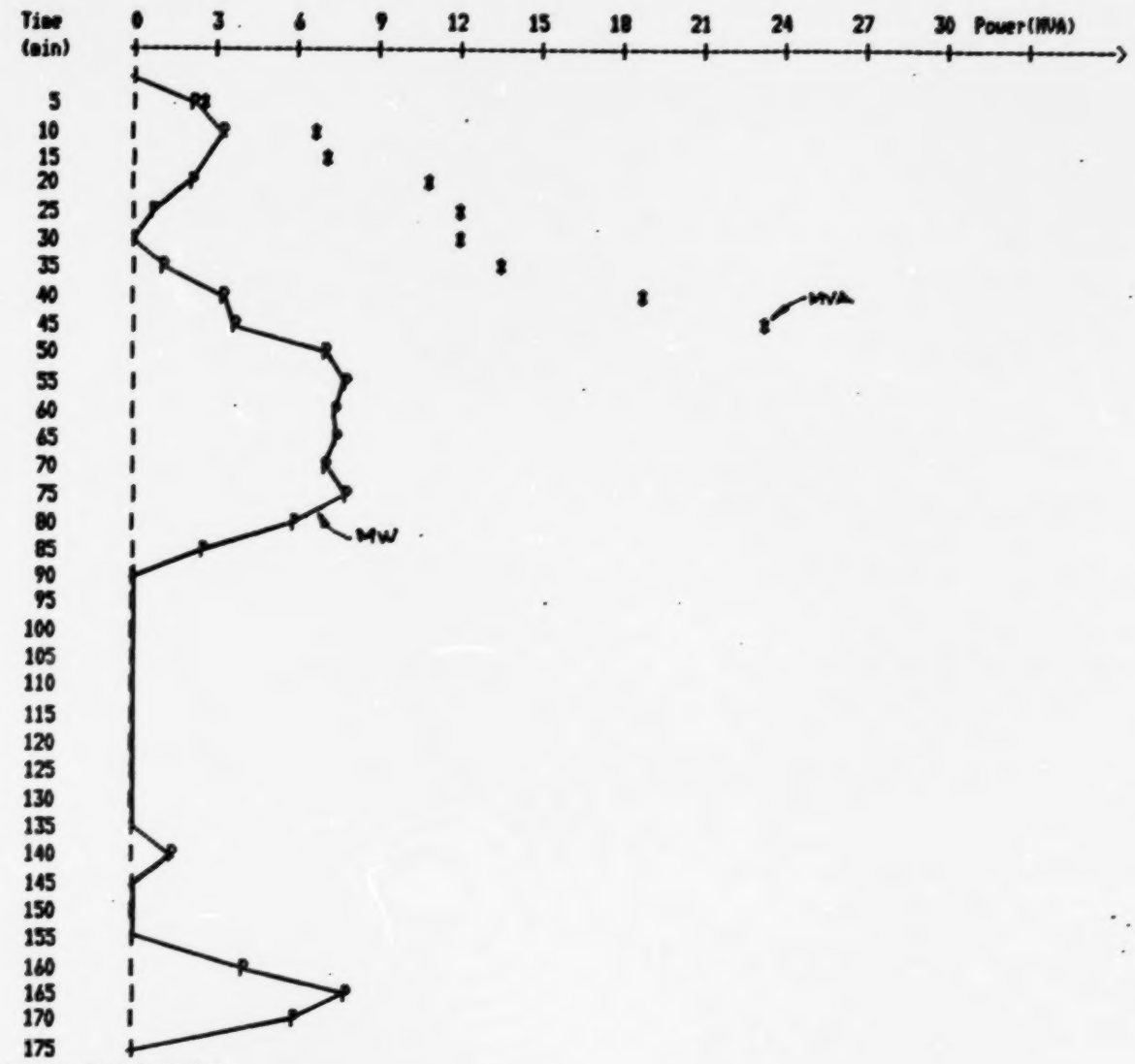
? V

fig. E·7

85/07/10

COAL TRAIN PERFORMANCE

B.C. RAIL - Engineering



Another Chart? (Y/N):
? Y
Select one of: S = SPEED vs TIME
L = Train LOCATION vs TIME
P = POWER vs TIME
V = VOLTAGE at the Train vs TIME
E = Exit.

? V

fig. E-8
p E-10

APPENDIX F

F1.0 VOLTAGE PROFILES

The TPC model discussed in Appendix E was modified using the power factor and efficiency characteristics of the GF6C locomotive (fig. E2 and E3).

The catenary impedances measured during the Tumbler Ridge commissioning tests were used. Modelling was performed using the train schedules shown in Appendix A. Minimum acceptable voltage at the pantograph was set at 39 kV. The model shows that:

1) adequate pantograph voltage can be maintained for the Prince George - Tacheeda section without the use of a series capacitor station.
2) the catenary feeder may be eliminated south of the Mile 484 substation.
3) the Tumbler Ridge substation will provide adequate pantograph voltage as far as McIntyre (Mile 525) if the series capacitor station is inserted into the circuit.

APPENDIX G

G1.0 An Electromagnetic Transients Program (EMTP) developed at the University of British Columbia by H.W. Dommel, J.R. Marti and L. Marti, was used to model the harmonic response of the catenary system. It was discovered that the system had a parallel resonance at the 11th harmonic as well as a theoretical infinite number of resonances at higher frequencies. An analysis of the current waveform at the pantograph indicated that 11th harmonic currents as high as 4% could be expected (see fig. G2). To control the harmonic overvoltages, a harmonic filter near Mile 484 will be required.

With the locomotive on-board filters off, the 3rd harmonic component of pantograph current is expected to reach 37% of the fundamental current (fig. G3). To reduce the total harmonic distortion on the 230 KV bus to an acceptable 2%, a third harmonic filter will be required at the Mile 484 substation. It is proposed that the power factor correction shunt capacitor be tuned with a step tapped air-core reactor to perform dual duty.

FIG. G1 LOCOMOTIVE 85 KM FROM SUBSTATION: PANTOGRAPH CURRENT/HARMONIC CONTENT VS SPEED

	HERTZ	5 KM/H ILE(RMS)	10 KM/H ILE(RMS)	15 KM/H ILE(RMS)	20 KM/H ILE(RMS)	25 KM/H ILE(RMS)	30 KM/H ILE(RMS)	35 KM/H ILE(RMS)
HARMONIC 1	60.00	72.1211	86.4398	97.8361	161.0500	165.8775	145.5426	129.3634
HARMONIC 2	120.00	0.0364	0.0441	0.0026	0.0069	0.0326	0.0104	0.0092
HARMONIC 3	180.00	12.2113	0.6776	10.4513	33.1222	22.6787	17.6118	13.3187
HARMONIC 4	240.00	0.0097	0.0125	0.0011	0.0063	0.0037	0.0047	0.0051
HARMONIC 5	300.00	13.0157	11.7406	2.0843	6.9465	16.4266	16.3702	14.1297
HARMONIC 6	360.00	0.0028	0.0080	0.0022	0.0023	0.0043	0.0018	0.0014
HARMONIC 7	420.00	2.7376	7.8107	5.5964	6.0485	2.4500	3.1262	6.3525
HARMONIC 8	480.00	0.0039	0.0087	0.0031	0.0014	0.0024	0.0010	0.0016
HARMONIC 9	540.00	5.1026	3.0405	4.9370	4.0898	3.0515	2.6924	1.2410
HARMONIC 10	600.00	0.0022	0.0087	0.0029	0.0003	0.0029	0.0007	0.0034
HARMONIC 11	660.00	2.9803	2.1688	3.5936	1.3895	3.1145	2.6805	1.7886
HARMONIC 12	720.00	0.0013	0.0072	0.0027	0.0003	0.0020	0.0007	0.0030
HARMONIC 13	780.00	1.5558	2.5593	2.5370	1.3690	2.2280	2.2208	2.0330
HARMONIC 14	840.00	0.0025	0.0057	0.0020	0.0019	0.0020	0.0006	0.0011
HARMONIC 15	900.00	2.0691	2.0188	1.4215	1.4731	0.7058	1.5458	1.5882
HARMONIC 16	960.00	0.0005	0.0048	0.0011	0.0013	0.0014	0.0006	0.0016
HARMONIC 17	1020.00	0.7739	0.8654	0.5479	0.6927	1.2712	0.5913	1.2448
HARMONIC 18	1080.00	0.0015	0.0043	0.0006	0.0006	0.0002	0.0007	0.0026
HARMONIC 19	1140.00	0.6757	0.4950	0.2423	0.6191	1.0565	1.2246	0.6905
HARMONIC 20	1200.00	0.0005	0.0028	0.0002	0.0006	0.0007	0.0000	0.0018
HARMONIC 21	1260.00	0.6253	0.6159	0.2730	0.7476	0.2930	0.9752	0.6819
HARMONIC 22	1320.00	0.0010	0.0015	0.0004	0.0007	0.0006	0.0004	0.0007
HARMONIC 23	1380.00	0.1222	0.4449	0.2825	0.1952	0.4149	0.1909	0.9017
HARMONIC 24	1440.00	0.0005	0.0006	0.0003	0.0005	0.0010	0.0006	0.0012
HARMONIC 25	1500.00	0.1687	0.1802	0.1322	0.4395	0.3122	0.4786	0.6765
HARMONIC 26	1560.00	0.0007	0.0003	0.0001	0.0006	0.0008	0.0004	0.0013
HARMONIC 27	1620.00	0.1956	0.2137	0.1017	0.4537	0.3020	0.4826	0.1682
HARMONIC 28	1680.00	0.0004	0.0010	0.0004	0.0001	0.0006	0.0002	0.0010
HARMONIC 29	1740.00	0.3205	0.1485	0.2530	0.0773	0.2463	0.1694	0.3567
HARMONIC 30	1800.00	0.0007	0.0016	0.0007	0.0004	0.0008	0.0002	0.0007
HARMONIC 31	1860.00	0.1437	0.1323	0.3699	0.3336	0.1958	0.1159	0.4396
HARMONIC 32	1920.00	0.0008	0.0020	0.0009	0.0005	0.0008	0.0004	0.0003
HARMONIC 33	1980.00	0.3423	0.3341	0.4034	0.2229	0.2306	0.0513	0.2449
HARMONIC 34	2040.00	0.0005	0.0019	0.0009	0.0008	0.0007	0.0001	0.0003
HARMONIC 35	2100.00	0.3140	0.3403	0.3386	0.1532	0.3989	0.1274	0.0422

FIG. G1 LOCOMOTIVE 85 KM FROM SUBSTATION: PANTOGRAPH CURRENT/HARMONIC CONTENT VS SPEED

	HERTZ	40 KM/H ILE(RMS)	45 KM/H ILE(RMS)	50 KM/H ILE(RMS)	55 KM/H ILE(RMS)	60 KM/H ILE(RMS)	90 KM/H ILE(RMS)
HARMONIC 1	60.00	132.3182	128.9826	119.1912	107.9498	103.0319	89.9507
HARMONIC 2	120.00	0.0234	0.0526	0.0423	0.0132	0.0701	0.0424
HARMONIC 3	180.00	12.8941	16.1992	17.8245	16.1890	15.4279	13.4664
HARMONIC 4	240.00	0.0111	0.0065	0.0056	0.0123	0.0125	0.0106
HARMONIC 5	300.00	7.9049	6.6312	10.4835	9.7645	9.4251	8.4342
HARMONIC 6	360.00	0.0060	0.0022	0.0018	0.0063	0.0059	0.0058
HARMONIC 7	420.00	6.9247	2.0592	5.3987	5.2634	5.1842	4.8687
HARMONIC 8	480.00	0.0017	0.0017	0.0009	0.0020	0.0020	0.0025
HARMONIC 9	540.00	4.1523	1.8104	2.6911	2.7596	2.7815	2.7815
HARMONIC 10	600.00	0.0018	0.0009	0.0007	0.0013	0.0014	0.0006
HARMONIC 11	660.00	2.3892	1.6090	1.5427	1.5335	1.5405	1.5814
HARMONIC 12	720.00	0.0016	0.0009	0.0005	0.0027	0.0027	0.0020
HARMONIC 13	780.00	1.5958	1.2993	1.2287	1.1190	1.0782	1.0049
HARMONIC 14	840.00	0.0008	0.0015	0.0003	0.0027	0.0027	0.0024
HARMONIC 15	900.00	0.9885	1.1998	1.0310	0.9583	0.9214	0.8011
HARMONIC 16	960.00	0.0016	0.0015	0.0003	0.0015	0.0018	0.0020
HARMONIC 17	1020.00	0.9273	1.0055	0.7760	0.7745	0.7661	0.6974
HARMONIC 18	1080.00	0.0005	0.0010	0.0004	0.0002	0.0005	0.0010
HARMONIC 19	1140.00	0.6604	0.7346	0.5544	0.5732	0.5816	0.5765
HARMONIC 20	1200.00	0.0007	0.0005	0.0004	0.0013	0.0010	0.0004
HARMONIC 21	1260.00	0.6392	0.6537	0.4492	0.4291	0.4299	0.4429
HARMONIC 22	1320.00	0.0003	0.0005	0.0002	0.0017	0.0016	0.0011
HARMONIC 23	1380.00	0.7736	0.6769	0.4125	0.3697	0.3556	0.3358
HARMONIC 24	1440.00	0.0012	0.0010	0.0001	0.0013	0.0015	0.0014
HARMONIC 25	1500.00	0.7297	0.6292	0.3614	0.3418	0.3290	0.2809
HARMONIC 26	1560.00	0.0017	0.0012	0.0003	0.0004	0.0008	0.0012
HARMONIC 27	1620.00	0.5942	0.5546	0.2886	0.2978	0.2968	0.2607
HARMONIC 28	1680.00	0.0008	0.0008	0.0003	0.0006	0.0003	0.0006
HARMONIC 29	1740.00	0.3254	0.4946	0.2324	0.2397	0.2466	0.2408
HARMONIC 30	1800.00	0.0006	0.0003	0.0003	0.0011	0.0009	0.0003
HARMONIC 31	1860.00	0.0269	0.4069	0.2138	0.1948	0.1975	0.2080
HARMONIC 32	1920.00	0.0008	0.0005	0.0001	0.0011	0.0012	0.0008
HARMONIC 33	1980.00	0.1816	0.2832	0.2054	0.1783	0.1714	0.1697
HARMONIC 34	2040.00	0.0009	0.0003	0.0001	0.0006	0.0009	0.0010
HARMONIC 35	2100.00	0.2448		0.1823	0.1726	0.1645	0.1411

FIG. G2 LOCOMOTIVE AT SUBSTATION: PANTOGRAPH CURRENT/HARMONIC CONTENT VS SPEED

	HERTZ	5 KM/H ILE (RMS)	10 KM/H ILE (RMS)	15 KM/H ILE (RMS	20 KM/H ILE (RMS)	25 KM/H ILE (RMS)	30 KM/H ILE (RMS)	35 KM/H ILE (RMS)
HARMONIC 1	60.00	66.4532	81.5316	92.5067	101.3809	125.4141	119.5326	111.3362
HARMONIC 2	120.00	0.0090	0.0177	0.0088	0.0125	0.0535	0.0060	0.0110
HARMONIC 3	180.00	19.0077	6.6286	6.6306	18.4116	46.3031	39.6999	30.5993
HARMONIC 4	240.00	0.0043	0.0120	0.0028	0.0117	0.0135	0.0008	0.0059
HARMONIC 5	300.00	12.8566	16.2213	8.5863	5.1769	15.9899	7.2032	13.6079
HARMONIC 6	360.00	0.0053	0.0111	0.0051	0.0098	0.0187	0.0013	0.0047
HARMONIC 7	420.00	6.0674	6.4817	10.0207	2.2056	4.2083	11.9942	8.9969
HARMONIC 8	480.00	0.0037	0.0118	0.0047	0.0078	0.0195	0.0013	0.0038
HARMONIC 9	540.00	6.2582	3.6005	6.0844	3.8385	5.1023	3.0586	4.4283
HARMONIC 10	600.00	0.0052	0.0107	0.0032	0.0086	0.0154	0.0006	0.0026
HARMONIC 11	660.00	2.5576	4.7124	2.9208	3.6681	2.9461	2.9121	3.0657
HARMONIC 12	720.00	0.0028	0.0099	0.0019	0.0084	0.0098	0.0009	0.0017
HARMONIC 13	780.00	3.5682	3.1899	1.9637	3.0305	1.5670	2.6881	2.1205
HARMONIC 14	840.00	0.0034	0.0096	0.0020	0.0066	0.0070	0.0007	0.0006
HARMONIC 15	900.00	1.8946	1.5613	2.2278	2.5275	0.9889	1.7947	1.9571
HARMONIC 16	960.00	0.0032	0.0086	0.0029	0.0056	0.0030	0.0007	0.0005
HARMONIC 17	1020.00	1.9593	2.1835	2.3145	2.0011	1.1712	1.7097	1.2975
HARMONIC 18	1080.00	0.0018	0.0075	0.0026	0.0054	0.0010	0.0007	0.0018
HARMONIC 19	1140.00	1.4999	1.7312	1.6460	1.3751	1.0348	1.1387	1.6287
HARMONIC 20	1200.00	0.0031	0.0067	0.0019	0.0040	0.0010	0.0004	0.0012
HARMONIC 21	1260.00	0.8575	0.8261	0.8653	0.8130	1.1620	1.2476	0.7445
HARMNOIC 22	1320.00	0.0011	0.0059	0.0010	0.0024	0.0050	0.0005	0.0016
HARMONIC 23	1380.00	1.0292	0.8979	0.5347	0.4158	0.4140	1.0173	1.3389
HARMONIC 24	1440.00	0.0017	0.0046	0.0009	0.0019	0.0040	0.0003	0.0008
HARMONIC 25	1500.00	0.3405	0.9030	0.6262	0.1394	0.8780	0.6460	0.7104
HARMONIC 26	1560.00	0.0013	0.0038	0.0013	0.0012	0.0050	0.0005	0.0006
HARMONIC 27	1620.00	0.5493	0.3623	0.6270	0.1392	0.2180	0.6295	0.9056
HARMONIC 28	1680.00	0.0002	0.0029	0.0011	0.0004	0.0005	0.0002	0.0004
HARMONIC 29	1740.00	0.2527	0.2866	0.3824	0.2423	0.4020	0.2941	0.6955
HARMONIC 30	1800.00	0.0012	0.0019	0.0007	0.0006	0.0003	0.0005	0.0003
HARMONIC 31	1860.00	0.1411	0.3321	0.1117	0.2517	0.2399	0.2511	0.4162
HARMONIC 32	1920.00	0.0004	0.0010	0.0004	0.0009	0.0024	0.0002	0.0005
HARMONIC 33	1980.00	0.1378	0.1523	0.1113	0.2208	0.1771	0.1911	0.6064
HARMONIC 34	2040.00	0.0002	0.0004	0.0003	0.0017	0.0010	0.0002	0.0010
HARMONIC 35	2100.00	0.2038	0.1322	0.1397	0.1859	0.1427	0.0233	0.1084

FIG. G2 LOCOMOTIVE AT SUBSTATION: PANTOGRAPH CURRENT/HARMONIC CONTENT VS SPEED

	HERTZ	40 KM/H ILE (RMS)	45 KM/H ILE (RMS)	50 KM/H ILE (RMS)	55 KM/H ILE (RMS)	60 KM/H ILE (RMS)	90 KM/H ILE (RMS)
HARMONIC 1	60.00	117.0897	119.3578	112.9282	106.5947	103.4127	89.1901
HARMONIC 2	120.00	0.0166	0.0162	0.0063	0.0187	0.0230	0.0596
HARMONIC 3	180.00	22.4342	16.6929	15.8443	18.5623	19.7543	16.1789
HARMONIC 4	240.00	0.0093	0.0063	0.0076	0.0030	0.0035	0.0113
HARMONIC 5	300.00	18.7756	15.9738	9.4867	9.0723	11.2330	8.6565
HARMONIC 6	360.00	0.0058	0.0041	0.0066	0.0015	0.0015	0.0050
HARMONIC 7	420.00	3.7450	9.8798	8.6396	4.0791	6.1795	4.3834
HARMONIC 8	480.00	0.0050	0.0070	0.0057	0.0006	0.0012	0.0028
HARMONIC 9	540.00	5.8949	1.8199	6.0537	2.3713	3.1891	2.1291
HARMONIC 10	600.00	0.0056	0.0009	0.0018	0.0016	0.0009	0.0013
HARMONIC 11	660.00	3.0508	2.6870	2.6228	2.2013	1.3497	1.2456
HARMONIC 12	720.00	0.0073	0.0015	0.0019	0.0015	0.0006	0.0006
HARMONIC 13	780.00	1.6579	2.5128	0.5186	1.9818	0.3031	1.1454
HARMONIC 14	840.00	0.0035	0.0021	0.0023	0.0007	0.0007	0.0011
HARMONIC 15	900.00	1.6657	1.5452	1.0913	1.5323	0.3953	1.0976
HARMONIC 16	960.00	0.0064	0.0019	0.0005	0.0013	0.0010	0.0016
HARMONIC 17	1020.00	1.5713	1.2759	1.0810	1.0924	0.6119	0.9344
HARMONIC 18	1080.00	0.0055	0.0013	0.0024	0.0022	0.0012	0.0018
HARMONIC 19	1140.00	1.3495	1.0434	0.9650	0.8407	0.6366	0.7333
HARMONIC 20	1200.00	0.0042	0.0007	0.0022	0.0023	0.0012	0.0018
HARMONIC 21	1260.00	0.8449	0.8628	0.8606	0.7205	0.5753	0.5852
HARMONIC 22	1320.00	0.0050	0.0007	0.0008	0.0019	0.0010	0.0015
HARMONIC 23	1380.00	1.0773	0.8997	0.7881	0.6083	0.5148	0.5083
HARMONIC 24	1440.00	0.0050	0.0011	0.0023	0.0017	0.0008	0.0011
HARMONIC 25	1500.00	1.1378	1.0916	0.8532	0.5266	0.4905	0.4496
HARMONIC 26	1560.00	0.0035	0.0011	0.0022	0.0020	0.0007	0.0007
HARMONIC 27	1620.00	0.3002	0.6417	0.7414	0.5448	0.4824	0.3726
HARMONIC 28	1680.00	0.0044	0.0009	0.0007	0.0021	0.0008	0.0007
HARMONIC 29	1740.00	0.9274	0.3606	0.3750	0.6037	0.4596	0.2964
HARMONIC 30	1800.00	0.0037	0.0004	0.0014	0.0017	0.0009	0.0010
HARMONIC 31	1860.00	0.6717	0.7488	0.2582	0.6110	0.4105	0.2731
HARMONIC 32	1920.00	0.0035	0.0003	0.0012	0.0011	0.0008	0.0011
HARMONIC 33	1980.00	0.2406	0.6945	0.5042	0.5427	0.3419	0.3090
HARMONIC 34	2040.00	0.0029	0.0006	0.0011	0.0010	0.0007	0.0010
HARMONIC 35	2100.00	0.6375	0.3344	0.5787	0.4255	0.2684	0.3514

APPENDIX H
DETAILED COST SUMMARY

(Annual coal tonnages - millions of tonnes)	8.5	13.5	17.0
CAPITAL COST SUMMARY			
POWER SUPPLY & CATENARY			
CATENARY:			
MATERIAL	$5,730,000	$5,730,000	$5,730,000
SOCIAL SERVICE TAX	401,000	401,000	401,000
INSTALLATION	2,695,000	2,695,000	2,695,000
ROAD BONDING	150,000	150,000	150,000
TOTAL CATENARY COST	8,976,000	8,976,000	8,976,000
POWER SUPPLY:			
FILTER STATION-			
MATERIAL	125,000	125,000	125,000
SOCIAL SERVICE TAX	9,000	9,000	9,000
INSTALLATION	125,000	125,000	125,000
TOTAL FILTER STATION COST	259,000	259,000	259,000
SUBSTATION -			
MATERIAL	1,800,000	1,800,000	1,800,000
SOCIAL SERVICE TAX	126,000	126,000	126,000
INSTALLATION	1,400,000	1,400,000	1,400,000
TOTAL SUBSTATION COST	3,326,000	3,326,000	3,326,000
HYDRO CONNECTION -	250,000	250,000	250,000
TOTAL POWER SUPPLY COST	3,835,000	3,835,000	3,835,000
SIGNAL MODIFICATIONS -	125,000	125,000	125,000
SUBTOTAL	12,936,000	12,936,000	12,936,000
ENGINEERING (10%)	1,294,000	1,294,000	1,294,000
CONTINGENCIES (15%)	1,940,000	1,940,000	1,940,000
CONSTRUCTION COST BEFORE INTEREST	16,170,000	16,170,000	16,170,000
INTEREST ON CONSTRUCTION (CONSTRUCTION COST /2*5/12*11%)	371,000	371,000	371,000
TOTAL CONSTRUCTION COST	16,541,000	16,541,000	16,541,000
ELECTRIC LOCOMOTIVES	11,416,000	11,416,000	11,416,000
CN REIMBURSEMENT	(6,800,000)	(6,800,000)	(6,800,000)
NET COST OF LOCOMOTIVES	4,616,000	4,616,000	4,616,000
TOTAL CAPITAL COST	$21,157,000	$21,157,000	$21,157,000

APPENDIX I
ANNUAL OPERATING COSTS/BENEFITS

(Annual coal tonnages - millions of tonnes)	Page Ref	8.5	13.5	17.0
ADDITIONAL OPERATING COSTS				
Catenary, Substation & Filter Station Maintenance	7	$235,000	$235,000	$235,000
Electric Locomotive Maintenance	6	355,000	355,000	355,000
Hydro Energy Charge	8	310,000	492,000	619,000
Hydro Demand Charge	8	363,000	363,000	363,000
Total Additional Costs		$1,263,000	$1,445,000	$1,572,000
OPERATING SAVINGS				
Motive Power Swap	8	67,000	106,000	133,000
Diesel Locomotive Maintenance	8	1,216,000	1,932,000	2,432,000
Diesel Fuel	8	2,079,000	3,304,000	4,159,000
Total Savings		3,362,000	5,342,000	6,724,000
NET ANNUAL SAVINGS		$2,099,000	$3,897,000	$5,152,000
Internal Rate of Return		6.8%	15.5%	20.7%

APPENDIX J
STATEMENT OF CASH FLOWS

(Annual coal tonnages - millions of tonnes)	8.5	13.5	17.0
YEAR			
0	($21,157,000)	($21,157,000)	($21,157,000)
1	525,000	974,000	1,288,000
2	2,099,000	3,897,000	5,152,000
3	2,099,000	3,897,000	5,152,000
4	2,099,000	3,897,000	5,152,000
5	2,099,000	3,897,000	5,152,000
6	2,099,000	3,897,000	5,152,000
7	2,099,000	3,897,000	5,152,000
8	2,099,000	3,897,000	5,152,000
9	2,099,000	3,897,000	5,152,000
10	2,099,000	3,897,000	5,152,000
11	2,099,000	3,897,000	5,152,000
12	2,099,000	3,897,000	5,152,000
13	2,099,000	3,897,000	5,152,000
14	2,099,000	3,897,000	5,152,000
15	2,099,000	3,897,000	5,152,000
16	2,099,000	3,897,000	5,152,000
17	2,099,000	3,897,000	5,152,000
18	2,099,000	3,897,000	5,152,000
19	2,099,000	3,897,000	5,152,000
20	2,099,000	3,897,000	5,152,000